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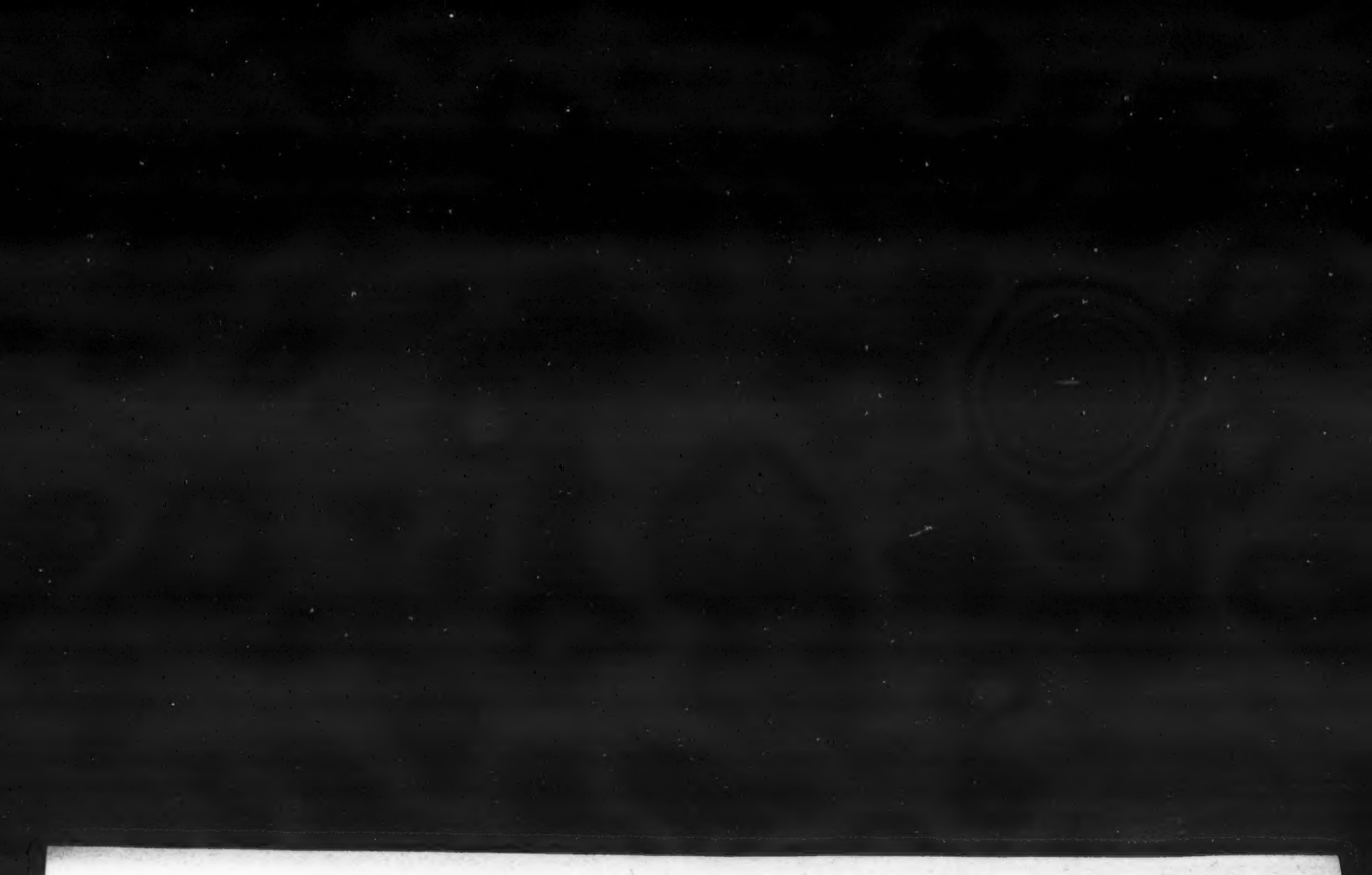


THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. I.—*The Inconsistencies of Utilitarianism as the Exclusive Theory of Organic Evolution;* by Rev. JOHN T. GULICK.

Natural Selection an Exclusive Theory with some Biologists.

IN a previous article, entitled "Divergent Evolution and the Darwinian Theory,"* I dwelt chiefly on the need of a bionomic theory that should explain polytypic, as well as monotypic, evolution. One of the chief deficiencies in Darwin's discussion of the "Origin of Species," is that he does not distinguish with sufficient clearness the conditions that are necessary for the transformation of an original species into a new species, when the former disappears in the process, leaving the latter to occupy its place, and the conditions that are necessary for the production of two or more species from one original species. In this paper it may be instructive to examine a vigorous attempt that has been made so to expound the theory of natural selection (which Darwin considered as inadequate to cover all the forms of monotypic evolution,) that it shall serve as the full explanation of both monotypic and polytypic evolution in all organisms lower than man. By confining our attention to Mr. Wallace's very interesting and suggestive volume on "Darwinism," we shall be better able to judge of the possibility of producing a self-consistent theory on this basis; but we should bear in mind that the same view is maintained by many naturalists, and that parallel statements abound in their writings. Mr. Wallace's volume not only embodies the mature reflections of one of the joint authors of

* This Journal, vol. xxxix, pp. 21–30.

the theory of natural selection, but it fairly represents that phase of biological theory which considers diversity of natural selection through exposure to different environments the only cause of divergence. The following passage will show the exclusive nature of his theory: "A great body of facts on the one hand, and some weighty arguments on the other, alike prove that specific characters have been, and could only have been, developed and fixed by natural selection because of their utility. We may admit that among the great number of variations and sports which continually arise many are altogether useless without being hurtful; but no cause or influence has been adduced adequate to render such characters fixed and constant throughout the vast number of individuals which constitute any of the more dominant species."—*Darwinism*, p. 142. This is in strong contrast with the following passage from the close of the Introduction of the sixth edition of the "Origin of Species," which is the last one that received the revision of the author: "I am fully convinced that species are not immutable, but those belonging to what are called the same genera are lineal descendants of some other and generally extinct species, in the same manner as the acknowledged varieties of any one species are the descendants of that species. Furthermore, I am convinced that Natural Selection has been the most important, but not the exclusive, means of modification." On page 421 of the same edition, Darwin calls attention to the fact that this passage has "been placed in a most conspicuous position" in the different editions of his work, and complains of the writers who misrepresent his conclusions on this point.

Facts that are Neglected or Denied.

Though Darwin maintains that besides the inherited effects of use and disuse and the direct action of the external conditions there are other forms of variation leading to permanent modifications of structure independently of natural selection (*Origin of Species*, 6th London ed., p. 421), he does not attempt to explain how these divergences arise. Neither Darwin nor Wallace appears to have observed, that, as in domestication, the isolated breeding of other than average forms, in whatever way it is secured, is the one necessary, and always effective, cause of divergence, so, in nature, wherever there arises the isolated breeding of other than average forms, there divergence will be produced; or that, as exposure to different environments is only one of the causes that lead isolated bands of men to desire and select different types of variation in the same species of animal, so exposure of wild species to different environments is only one of several classes of

causes that may subject isolated portions of one of these species to different forms of selection, producing divergence; or, again, that as differences in the uses to which men put an animal are not necessarily useful differences, so the differences in the uses which isolated portions of a species make of the environment, though they produce diversity of natural selection, leading to permanent divergence, are not necessarily useful differences. These, with other allied doctrines, which were presented in my paper on "Divergent Evolution Through Cumulative Segregation," have received adverse criticism from Mr. Wallace in the work mentioned above. He says: "In Mr. Gulick's last paper (*Jour. of Linn. Soc.*, Zoology, vol. xx, pp. 189–274), he discusses the various forms of isolation above referred to, under no less than thirty-eight different divisions, with an elaborate terminology, and he argues that these will frequently bring about divergent evolution without any change in the environment or any action of natural selection. The discussion of the problem here given will, I believe, sufficiently expose the fallacy of his contention, but his illustrations of the varied and often recondite modes by which practical isolation may be brought about, may help to remove one of the popular difficulties in the way of the action of natural selection in the origination of species." (Note on p. 150).

In this passage Mr. Wallace seems to take issue with each and all of my propositions; but after a careful study of his whole discussion, one cannot but be in doubt whether he fully dissents from any of them. This uncertainty arises either from his failing to recognize distinctions which I have made, or from ambiguities and inconsistencies in his own statements.

Extending the meaning of Natural Selection does not save the Theory.

He represents me as contending that divergent groups are frequently found in which the action of natural selection is wanting. He here fails to distinguish between the absence of diversity in the action of natural selection and the absence of any action of the same principle. I have never maintained that any species can long escape the action of natural selection; but I have that natural selection cannot produce transformation of a race unless it secures the propagation of other than average forms of that race; that it cannot be a cause of divergence unless to this condition is added the independent generation (i. e., isolation) of groups that are subjected to some diversity in its action; and, that, in isolated groups, some of the divergent characters may be due to other causes of trans-

formation. In the passage I have quoted from p. 142, he expresses great confidence in the proof that all specific characters are developed and fixed by natural selection; but in the discussion that follows concerning the influence of natural selection, he claims as belonging to this principle sets of influences which are usually included under sexual selection, and which he cannot regard as due to the reactions between the species and its environment. (See *Darwinism*, pp. 282–5), and, even then, it is found too narrow to cover all the facts of specific divergence; for, when he comes to consider the origin and development of accessory plumes, he has to abandon the theory to which he has clung through the greater part of the book. Speaking of the enormously lengthened plumes of the "bird of paradise and of the peacock," he says, on page 293, "The fact that they have been developed to so great an extent in a few species is an indication of such perfect adaptation to the conditions of existence, such complete success in the battle of life, that there is, in the adult male at all events, a *surplus of strength, vitality and growth power, which is able to expand itself in this way without injury.* That such is the case is shown by the great abundance of most of the species which possess *these wonderful superfluities* of plumage. * * * *Why, in allied species, the development of accessory plumes has taken different forms, we are unable to say, except that it may be due to* that *individual variability* which has served as the starting point for so much of what seems to us to be strange in form or fantastic in color, both in the animal and vegetable world." (The italics are mine.) According to the theory he has elsewhere maintained, *these superfluities* of form and color which are not controlled by natural selection should present, "a series of inconstant varieties mingled together, not a distinct segregation of forms" (p. 148); but in this passage he teaches that they have assumed different forms in allied species. On p. 141 he maintains that characters which are neither beneficial nor injurious are from their very nature unstable and cannot become specific, while here he offers a suggestion as to how they have become specific. There is then a problem that presses for solution, namely, the explanation of permanent divergence in characters that are useless without being hurtful (p. 142), unless he considers his suggestion "that it may be due to individual variability" an adequate explanation; and I presume he does not. On page 142, he says of characters that are "useless without being hurtful:" "No cause or influence has been adduced adequate to render such characters fixed and constant; but in speaking of "the delicate tints of spring foliage, and the intense hues of autumn," he says: "As colors they are unadaptive, and appear to have

no more relation to the well-being of the plants themselves than do the colors of gems and minerals. We may also include in the same category those algæ and fungi which have bright colors—the red snow of the Arctic regions, the red, green, or purple seaweeds, the brilliant scarlet, yellow, white, or black agarics, and other fungi. All these colors are probably the direct results of chemical composition or molecular structure, and being thus normal products of the vegetable organism, need no special explanation from our present point of view; and the same remark will apply to the varied tints of the bark of trunks, branches and twigs, which are often of various shades of brown and green, or even vivid reds or yellows" (p. 302). He here seems to admit that instead of useless specific characters being unknown, they are so common and so easily explained by "the chemical constitution of the organism" that they claim no special attention.

Inconsistency in extending the meaning of Environment.

If Mr. Wallace accepts the definition of natural selection which makes it the survival of those members of a species which are best fitted to its environment (and this is the scope he seems to assign to it in the earlier half of Chapter V where the matter is under special discussion), then he ought to admit that changes in a species produced by the action of the members of the species on each other although they are adaptive are not due to natural selection. If, on the other hand, natural selection is made to include the actions and reactions of the species on itself (and this he does on pages 282–5), then certainly he ought to admit that there may be changes in the action of natural selection without any change in the relations of the species to the environment. One way to escape this dilemma is to extend the definition of the environment so as to include every influence that affects the species, whether it is within the species, or external to it; but this reduces his doctrine, that without change in the environment there is no change in the organism, to the fruitless truism that without some cause there is no change in the organism. An example of Mr. Wallace's extending the meaning of the environment so as to include the action of the members of a species on each other, is found on page 149. After mentioning several arguments intended to show the impossibility that isolated portions of a species should diverge while exposed to the same environment, he remarks, "It is impossible that the environment of the isolated portion can be exactly like that of the bulk of the species. It cannot be so physically, since no two separated areas can be exactly alike in climate and soil; and, even if

they are the same, the geographical features, size, contour, and relation to winds, seas and rivers would certainly differ. Biologically, the differences are sure to be considerable. The isolated portion of a species will almost always be in a much smaller area than that occupied by the species as a whole, hence it is *at once in a different position as regards its own kind.*" He then enumerates several differences in the biological environment that are liable to occur; but the point I wish now to note is, that he mentions as one of the differences in the environment the "*different position as regards its own kind.*" This is exactly the difference which, in so far as it is the prevention of intercrossing and the consequent unification of endowments and habits, constitutes isolation; and unless he is able to show that this difference is incapable of producing any divergence, his contention is unsustained. But he here yields the point at issue, by mentioning this amongst the effective differences. The only way to escape the force of his concession is to claim, as he virtually does here, that isolation, being the separation of the isolated fragment from the influence of the original stock, is in itself a difference in the environment. By taking this position, however, he involves himself in another contradiction; for, if isolation is a difference in the environment, why does he deny that it has a direct influence in producing change in the organism?

Diversity of Natural Selection during exposure to the same Environment.

Another discrepancy in Mr. Wallace's theory is that, while he rightly assigns great importance to diversity of natural selection arising from divergent habits in appropriating the resources of the same environment, exhibited by different sections of the same species occupying the same area, he, nevertheless, insists that the representatives of a species, isolated in different areas of the same environment, will be neccessarily subjected to the same influences from natural selection, and will inevitably maintain the same characters and of course, the same habits. That he believes divergent habits may arise, when the divergent groups are occupying the *same area*, and are prevented from crossing simply by the divergence of habits, will be seen by the case of the varieties of wolves mentioned on p. 105, and by some of the cases mentioned on pp. 108 and 117; also by the statement, on p. 119, that—"When one portion of a terrestrial species takes to a more arboreal or a more aquatic mode of life, the change of habits itself leads to the isolation of each portion," and by a similar statement at the bottom of p. 145. That he believes

there can be no change, either of habits or structure, when portions of the same species are isolated in *different areas* under the same environment, appears from the statement on p. 149, that—"If the average characters of the species are the expression of its exact adaptation to its whole environment, then, given a precisely similar environment, and the isolated portion will inevitably be brought back to the same average of characters." And this he maintains will be the case even "if we admit, that, when one portion of a species is separated from the rest there will necessarily be a slight difference in the average character of the two portions."

Does the Difference in the Environment increase with each successive Mile?

If the divergences presented by the Sandwich Island land mollusca are wholly due to exposure to different environments, as Mr. Wallace argues on pages 147–150, then, there must be completely occult influences in the environment that vary progressively with each successive mile. This is so violent an assumption that it throws doubt on any theory that requires such support. Of all the suggestions made by Mr. Wallace concerning possible and inevitable differences in the environments presented in the successive valleys, it seems to me not one meets the requirements of the case, or throws any light on the subject. The one suggestion which is quite applicable as an explanation is the one already quoted that "the isolated portion is at once in a different position as regards its own kind." This is, I believe, a most potent difference, which (as Mr. Wallace's language seems to indicate), is directly introduced by isolation, and (adhering to the meaning usually given to environment,) is not at all due to difference in the environments presented in the different areas.

Unstable Adjustments disturbed by Isolation.

There is a sentence in another chapter of Mr. Wallace's book which attributes to isolation (though without recognizing the important results that must follow) just that kind of influence in introducing a certain class of physiological divergences, which I claim for it in introducing, not only physiological, but also psychological and morphological divergences. I claim that there is, in many species, more or less variation with unstable adjustment, in the habits which determine what forms of food it shall appropriate, and that, when a few individuals of such a species (the offspring perhaps of a single female) are isolated, this adjustment is often so disturbed by

the failure of the few individuals to completely represent the average character of the species and by their being freed from competition, and wide interbreeding with those of their own kind, that divergent habits of feeding are formed. I further claim that for the production of this result it is not at all necessary that the environments presented in the isolated districts should differ in any respect. Indeed if all but one pair of a variable species should be destroyed, the descendants of that pair, remaining in the same area and under the same environment, would probably differ more or less from the original stock. Those that breed together must have habits that enable them to do so; and the offspring of those that interbreed widely will for the most part, inherit the powers and habits that enabled their ancestors to interbreed widely; but if the offspring of a single family are carried to an isolated area presenting the same environment, there will be nothing to ensure the perpetuation of exactly the original powers and habits, unless the power of heredity is such that each pair is sure to transmit the complete average character of the whole species; and this is not the condition of all species that pair, if of any. Within the limits of each freely interbreeding portion of a species a mutual harmony and adjustment of habits is preserved, because it is the condition of propagation within those limits; but between portions that are prevented from interbreeding there is nothing but heredity to prevent divergence in the kinds of adjustment; and in variable species, the probability is that divergence will in time show itself more or less distinctly. Though Mr. Wallace considers this reasoning fallacious when applied to divergence in habits he uses an exactly parallel reasoning in the portion of the following passage which I designate by italics. "*It appears as if fertility depended on such a delicate adjustment of the male and female elements to each other, that, unless constantly kept up by the preservation of the most fertile individuals, sterility is always liable to arise. . . . So long as a species remains undivided, and in occupation of a continuous area, its fertility is kept up by natural selection; but the moment it becomes separated, either by geographical or selective isolation, or by diversity of station or of habits, while each portion must be kept fertile inter se, there is nothing to prevent infertility arising between the two separated portions.* As the two portions will necessarily exist under somewhat different conditions of life, and will usually have acquired some diversity of form and color—both which circumstances we know to be either the cause of infertility or to be corelated with it—the fact of some degree of infertility usually appearing between closely allied but locally or physiologically segregated species is exactly

what we should expect" (p. 184–5). Notwithstanding this statement he does not seem to have grasped the idea, that in the geographically isolated portions as well as in the others, the "different conditions of life" of which he speaks, may be the different relations to the environment into which the separated portions are brought by their divergent habits, without any reference to inevitable differences in the size and contours of the different areas or in any other features of the environments; and that the divergence in the habits may be directly due to the prevention of interbreeding between separated portions which inevitably differ in average character, especially if they are very small portions.

Isolated portions differ in varying degrees from the average character of the Species.

The italicized portion of the passage last quoted attributes to isolation, in stronger language than I should be willing to use, a direct influence in producing divergence in the adjustments on which fertility in the different portions of the species depend. I should prefer to say that in *some species* the adjustments on which fertility depends are so delicate that, adjustments producing perfect fertility within one intergenerating portion of the species, will not produce fertility in another portion that has been long isolated. I do not make my statements so sweeping as his concerning the divergent influence of isolation on any one class of characters, but I include all classes of inheritable characters, in sexually producing organisms, as coming under its influence. I also insist that the direct influence of isolation in producing divergence is in proportion to the degree of segregation, which varies immensely in different forms of isolation which are equally complete as preventives of intercrossing. A very stable and homogeneous species may be divided by geological subsidence into two large sections, each represented by a vast number of individuals. In such a case the difference in the average character, and consequently the degree of segregation, of the two sections will be infinitesimally small, and the influence of the isolation thus produced will chiefly consist in its preserving in the different sections any diversities that may arise in the effects of natural selection, or of other principles of transformation. The isolation between the land animals of Ireland and Britain, which Mr. Wallace cites as adverse to my theory, is of this kind. Again, there may be transportation and isolation of very small fragments of a very variable species. In such a case separation may involve a degree of segregation that from the first produces perceptible divergence. Again, the process by which

the isolation is produced may be in itself segregative, in that it brings together those endowed in some special way, causing them to breed together, and preventing them from breeding with others. This is especially the case with Sexual, Social, and Prepotential, Segregation, and in some degree with Industrial Segregation. Isolation thus produced is in its very nature segregative, and would result in divergence if diversity of natural selection did not arise in the different sections of the species. Segregation with divergence may also be produced by natural selection or some other principle of transformation co-operating with some form of isolation that of itself is not perceptibly segregative. As segregation of other than average forms always produces divergence, and without it there is no divergence, I claim that it is the fundamental principle of divergent or polytypic evolution. Natural selection, which is the exclusive propagation of those better adapted to the environment, when it results in the preservation of other than average forms, produces confluent or monotypic evolution; but it is never the cause of divergence, except when co-operating with some principle of isolation in such a way that the two principles produce segregation. Failure to recognize these distinctions, prevents Mr. Wallace from understanding my theory, and leads him to represent me as claiming for isolation all that I claim for segregation.

Incompatibilities arise during Positive Segregation.

On pages 173–186, Mr. Wallace maintains that "Natural selection is, in some probable cases at all events, able to accumulate variations in infertility between incipient species" (p. 174); but his reasoning does not seem to me conclusive. Even if we grant that the increase of this character occurs by the steps which he describes, it is not a process of accumulation by natural selection. In order to be a means of cumulative modification of varieties, races or species, selection, whether artificial or adaptational, must preserve certain forms of an intergenerating stock, to the exclusion of other forms of the same stock. Progressive change in the size of the occupants of a poultry-yard may be secured by raising only bantams the first, only common fowls the second, and only Shanghai fowls the third year; but this is not the form of selection that has produced the different races of fowls. So in nature rats may drive out and supplant mice; but this kind of selection modifies neither rats nor mice. On the other hand, if certain variations of mice prevail over others through their superior success in escaping their pursuers, then modification begins. Now, turning to p. 175, we find that in the illustrative case

introduced by Mr. Wallace, the commencement of infertility between the incipient species is in relations to each other of two portions of a species that are locally segregated from the rest of the species, and partially segregated from each other by different modes of life. These two local varieties, by the terms of his supposition, being better adapted to the environment than the freely interbreeding forms in other parts of the general area, increase till they supplant these original forms. Then, in some limited portion of the general area, there arise two still more divergent forms, with greater mutual infertility and with increased adaptation to the environment, enabling them to prevail throughout the whole area. The process here described, if it takes place, is not modification by natural selection. The natural selection of which he speaks does not arise till, with each advancing step, a new and complicated adjustment (which introduces the two new forms, each with unabated fertility with its own kind but with diminished fertility with the other kind) has been attained by some other process. That other process is the one described in the passage I have already quoted from pp. 184–5, where, according to my apprehension, the cause of divergence is more correctly stated than it is in the passage now under consideration. In the latter part of my paper on *Divergent Evolution through Cumulative Segregation* I have shown that the different kinds of incompatibility, preventing complete fertility between incipient species (and there called forms of Negative Segregation), cannot arise except as accompaniments of Positive Segregation in some form; but that, having once arisen in connection with partial Positive Segregation, they increase from generation to generation by a law that is quite distinct from natural selection. It was also shown that endowments only partially segregative (as, for example, somewhat divergent habits of feeding), when not concurrent with any forms of cross incompatibility, are liable to be obliterated by crossing; but, when associated with segregate fertility and cross infertility, will increase from generation to generation, even if the mongrels are as well adapted to the environment as the pure forms. I at the same time called attention to the fact that, when associated with some form of partial positive segregation (as divergent habits of feeding, or segregative sexual and social instincts), greater vigor, of pure forms, as contrasted with the mongrels, would have the same effect as their greater fertility. In other words, Segregate Vigor would preserve a partially segregated variety as effectual as Segregate Fecundity.

Incompatibilities will disappear unless preserved by Positive Segregation.

Mr. Wallace has given a very instructive computation on pages 181–4; but it does not seem to me to prove, as he supposes, that infertility between the individuals of a species cannot increase "unless correlated with some useful variation," but that it cannot arise, except as a transitory variation, unless associated with some positively segregative principle, causing those to pair together which are fertile with each other. My contention is that, without some positive form of segregation fecundity and cross sterility can never arise; and that after it has arisen under segregation, no amount of correlation with useful variation will preserve it, if the positive segregation is removed. If, for example, all the species of humming birds were brought together in one country, and were deprived of all segregative habits and instincts, it certainly would not require many generations to reduce them to one species. If equally adapted to the environment, the species that would succeed in perpetuating itself would be the one represented by the largest number of individuals; or if several species were entirely cross fertile and were in the aggregate represented by a larger number of individuals than any other similar group of species or than any single species, then, the resulting species would be the hybrid descendants of this most numerous group. All the other species would become extinct through failing to mate with "physiological complements."

Why any need of distinctive Recognition Marks for those whose Ancestors had but one set of Marks.

An example of one of the effects of divergence being treated as if it were the primary cause of divergence is found on pages 217–228 and 284, where the need of distinctive characters for easy recognition is given as the chief cause of divergence in calls, odors, and colors. The importance of distinctive characters by which the members of a species may distinguish their mates from those of other species cannot be exaggerated; but how does it happen that the descendants of one stock which had originally but one set of such characters, have become segregated into groups, needing distinctive marks. By confounding the problem of successive, monotypic adaptation with that of coexistent, polytypic adaptation the real causes of divergence have been obscured and misapprehended. The diversity of Sexual and Social Selection, which Mr. Wallace in these passages speaks of as natural selection, is due to diversity of sexual and social instincts which in their turn have been produced by different forms of segregation. For a

fuller exposition of this subject I would refer to my paper on "*Divergent Evolution through Cumulative Segregation*" (Linn. Soc. Jour. Zoology, vol. xx, pp. 234–8). The principles which I have called Sexual and Social Segregation, Mr. Wallace has mentioned in several places under the name "selective association," or "selective isolation," but he does not recognize the fact that, whenever this principle segregates forms whose immediate ancestors were not segregated, it must be the direct cause of divergence; and that, when divergent forms that have arisen under Industrial and Local Segregation are brought together through increase of numbers, this principle is often the one cause preserving varieties that would otherwise be obliterated. With plants whose pollen is distributed by the wind, and probably with both vegetable and animal forms whose fertilizing elements are distributed by water, Prepotential Segregation plays the same role as the segregative instincts of higher animals. As this principle depends on the greater rapidity with which the male and female elements of the same variety or species combine, as contrasted with the elements of different varieties and species, we might call it isolation through selective impregnation, just as Mr. Wallace has called the instinctive segregation, "isolation through selective association." Whatever names we give these two principles, they must be important factors in divergent evolution.

Segregation produces Domestic Races, why not Species?

Mr. Wallace seems to be opposed to the idea that some form of isolation is essential to divergence; but in his argument he yields so much that I cannot but think his opposition is largely due to his misinterpreting the theory. Mr. Romanes has mentioned eight or ten forms of isolation; and Mr. Wallace says I have discussed thirty-eight forms; but neither of us claim that these are the only possible forms; nor do we claim that any form of this principle is essential to the transformation of one species into another when the original one disappears in the process. The phrase "new species" as used by Mr. Wallace in the following passage is ambiguous; but the second sentence seems to indicate that he is here discussing divergence as well as simple transformation. He says: "Most writers consider the isolation of a portion of a species a very important factor in the formation of new species, while others maintain it to be absolutely essential. This latter view has arisen from an exaggerated opinion as to the power of intercrossing to keep down any variety or incipient species and merge it in the parent stock. But it is evident that this can only occur with varieties that are not useful, or which, if

useful, occur in very small numbers." . . . (p. 144). Near the end of the same chapter, after presenting arguments in favor of this position, and after reviewing some of the facts which I have presented concerning the divergences of Sandwich Island land molluscs, he remarks—"We have, however, seen reason to believe that geographical or local isolation is by no means essential to the differentiation of species, because the same result is brought about by the incipient species acquiring different habits or frequently a different station; and also by the fact that different varieties of the same species are known to prefer to pair with their like and thus to bring about a physiological isolation of the most effective kind" (p. 150). Except that he has used "physiological isolation" where I should have used psychological segregation, this last passage is as completely in accord with what I have presented in my paper on "*Divergent Evolution*" as it could have been if he had copied my statements. But how is this passage, and one of similar import on page 185, to be reconciled with his own statement just quoted from page 144. On pages 217, 218 and 226, he bases his argument for the importance of different coloration in closely allied species on the obvious necessity for means "to secure the pairing together of individuals of the same species," if a new species is to be kept "separate from its nearest allies." He here assumes the fundamental fact on which the theory of segregation rests. All that is wanting is its recognition as a universal principle on which all permanent divergences, whether varietal or specific necessarily depend. In the formation of domestic variations it is fully recognized; for he says, "It is only by isolation and pure breeding that any specially desired qualities can be increased by selection" (p. 99). If experimental biology shows this to be a constant law, is there any good reason for not applying it in the general theory of organic evolution? Seeing it is admitted that artificial selection, unaided by isolation, is of no avail in producing divergent races, how can it be claimed that natural selection, unaided by isolation, is of any avail in producing varieties and species. Again, as in domestication, the segregate breeding of other than average forms always produces divergence, have we any reason to doubt that, when the same process takes place in the grouping of organisms in a natural state, the result will also be divergence?

The discrepancies to which I have referred are it seems to me due to deficiencies in the theory which Mr. Wallace maintains in common with many others. These problems that drive the exclusive utilitarian into various inconsistencies, can, I am convinced, be consistently explained by the theory of Divergence through Segregation.

26 Concession, Osaka, Japan.

ART. II.—*The Southern Extension of the Appomattox Formation;* * by W J McGEE.

CONTENTS: Introduction, p. 15—General Characters and Relations, p. 19—Geographic Distribution, p. 28—Hypsographic Distribution, p. 30—Stratigraphic Relations, p. 31—Taxonomy, p. 33—Sources of Materials, p. 34—Interpretation, p. 35.

INTRODUCTION.

IN a paper entitled "Three Formations of the Middle Atlantic Slope," published in the American Journal of Science early in 1888,† a distinctive late Tertiary formation, well displayed on the Appomattox river in eastern Virginia, was defined and named after that river; and its principal characters, its distribution, its stratigraphic relations, and its probable age were briefly recorded. The formation was then known to consist of a series of predominantly orange-colored, nonfossiliferous sands and clays, resting unconformably upon Miocene and older formations, and unconformably overlain by the Columbia formation; it was known to expand southward, from a thin and discontinuous bed exposed in a narrow belt on the Rappahannock river, so rapidly as to form a terrane many miles in width on the Roanoke; and it was inferred to represent at least a part of the Orange Sand of Hilgard and other southern geologists.

The several lines of research concerning the phenomena of the Middle Atlantic slope recorded in this paper have recently been extended southward into the Carolinas, Georgia, Alabama, and Mississippi; and some of the results of the work are deemed worthy of publication.

The Coastal Plain commencing in the Middle Atlantic slope at Sandy Hook extends southwestward to the southeastern angle of the continent forming Florida, and thence westward and southwestward to the boundary of the national domain on the Rio Grande. Throughout the sweep of nearly two thousand miles from the mouth of the Hudson to the lower Mississippi, the geographic division so trenchantly defined in the Middle Atlantic slope is well marked, although its inner boundary is less conspicuous in the south than in the north; for in the Southern Atlantic and Eastern Gulf slopes it is commonly crossed at right angles by the rivers (the Alabama alone marking it for a considerable distance), while in the Middle Atlantic slope the principal waterways depart from their normal direction to follow its course, and thus give origin to one of the most strongly marked physiographic features of

* Read before the Geological Society of America, Dec. 27, 1889.

† Third Series, vol. xxxv, pp. 120–143, 328–330, 367–388, 448–468.

the globe. Yet in the south as in the north the boundary is the most important structural line of eastern United States: it marks the junction of the unconsolidated and practically undisturbed Neozoic clastics on the seaward side, at first with the greatly disturbed crystallines, and then with the corrugated, folded, and everywhere completely lithified Paleozoic strata of the southern Appalachians; on reaching it every stream, great and small, is broken by a rocky rapid, a great fall, or a cascade, and these lines of rapids, falls, and cascades extend from the Roanoke almost to the Mississippi. And in the Southern Atlantic and Eastern Gulf slopes, as in the Middle Atlantic zone, the boundary is an important cultural line: Most of the leading southern cities are built at the falls of the rivers, and their industries are determined by the water-power which the rivers afford; the rivers are commonly navigable below and unnavigable above the falls, and the original means of traffic were thus diverse, and this diversity persists in some measure to-day; while the soils on opposite sides of the boundary are essentially distinct, and so the industries growing out of the soil and its products are commonly sharply contrasted. Among the southern cities located on the fall-line are Columbia, Augusta, Macon, Columbus, Montgomery and Tuscaloosa. The Coastal Plain lying between this great structural, physiographic, and cultural boundary of Nature's drawing and the still more trenchant boundary marked by the shores of the Atlantic and Gulf, is a lowland zone, concentric with the continent save as expanded by the Floridian peninsula, and scored radially by drainage lines, of which many expose its structure.

This is the area in which the Appomattox formation is found; and throughout the greater part of this area, the formation is well developed and wonderfully presistent in composition, structure, and stratigraphic relations.

In order to set forth clearly the phenomena of the Appomattox formation in its southern extension, it is necessary to note briefly the characteristics in the southern states of the two great data-formations representing the beginning and the ending of Neozoic time in the Middle Atlantic slope—the Potomac and the Columbia.

About its type locality (the District of Columbia), the Columbia formation exhibits two phases, i. e., a *fluvial phase*, consisting of brick-clay or loam graduating downward into a gravel or bowlder bed; and an *interfluvial phase*, consisting largely of debris derived from the immediately subjacent formations, rearranged, intermixed with a variable element of far traveled material brought down by the rivers, and re-

deposited in a sheet of variable thickness, ranging from a trifling veneer near the fall-line and at high levels to a considerable bed of stratified deposits toward the coast. In the Southern Atlantic and Eastern Gulf slopes, the formation in like manner consists commonly of two principal phases and several local varieties; yet all are connected by stratigraphic continuity: In North Carolina the relations displayed in the District of Columbia are maintained, save that the interfluvial phase becomes progressively more and more sandy in crossing the state from north to south, and finally passes into the essentially continuous veneer of sandy loam or fine sand completely covering the seaward portion of the Coastal Plain from the Neuse river to Mobile bay; in South Carolina the fluvial phase becomes transformed into a sandy or silty loam flanking the rivers in low terraces locally known as "second bottoms," while the interfluvial phase is represented by the wide-spread mantle of pine-clad sands stretching scores of miles inland from the coast—though the fluvial phase is sometimes removed and the interfluvial phase is more profoundly eroded than in either higher or lower latitudes; in Georgia the two phases of the formation are similar to those displayed in South Carolina save that both have suffered less from erosion; in central Alabama the fluvial phase is represented upon the principal rivers by extensive "second bottom" loam (which is, on the Chattahoochee, indistinguishable from the Columbia loam either in hand specimens or in hillsides), while in southern Alabama the loam becomes sandy and expands into a superficial mantle of pine-clad sands entering the state from Georgia in a hundred-mile zone which narrows to a twenty-mile belt west of Mobile bay; in northeastern Mississippi the fluvial deposits are similar to those of northern Alabama, and to the southward they pass into the low-lying sand-plain entering the State from the east; but toward the mouth of the Mississippi the sand-flats narrow, and the sands pass into a series of silts and clays with intercalated sand-beds which are, according to Johnson,* stratigraphically continuous with, and

*The correlation of the Port Hudson with the Columbia represents the only link in the series which was not established by personally tracing stratigraphic continuity from section to section and from phase to phase on the ground. It is just to say that the coast sands and subjacent clay beds of southeastern Mississippi, the Port Hudson, and the loess with its basal gravel bed, were independently and antecedently correlated by Mr. Lawrence C. Johnson of Mississippi, and that the well defined Columbia deposits of the Roanoke river have been stratigraphically connected with the coast sands and "second bottom" deposits of North Carolina by Prof. Joseph A. Holmes of the University of North Carolina, both of whom are engaged in geologic investigations of the Coastal Plain under the auspices of the U. S. Geological Survey and the direction of the author; and it is a source of gratification to be able to state that the observations and inferences of these geologists are in all respects corroborative of the work recorded herein.

but another phase of, the Port Hudson of Hilgard; while in western Mississippi the fluvial phase of the Columbia passes into and is finally replaced by the vast body of loess with subjacent gravel beds flanking the Mississippi river. These various deposits are stratigraphically continuous, and form a single and indivisible genetic unit; they were evidently laid down during a single submergence of the southeastern coast, extending from the terminal moraine at the mouth of the Hudson to and beyond the Mississippi river; and the local variations in composition and structure are evidently due to simple and easily ascertained local conditions.

The Columbia formation represents the first great episode of cold in the Pleistocene; and by reason of the recent work on its southern extension, it is now possible to map with approximate accuracy the geography of the southeastern part of the continent during that episode.

In its type locality the Potomac formation is a brackish water littoral deposit made up of gravel and cobble-stones of quartz and quartzite (derived respectively from the Blue Ridge and from the veins intersecting the Piedmont gneisses), arkose (derived immediately from the Piedmont schists and granites), sand, derived from all these sources, and a considerable element of clay; and its age is probably early Cretaceous or late Jurassic—the abundant plant remains indicating the former period, and the less abundant vertebrate remains denoting the latter. South of the Appomattox river the continuity of the terrane is broken by erosion, and its surface is sometimes concealed by newer deposits; but exposures are sufficiently frequent to warrant the conclusion that the Potomac formation is stratigraphically continuous with the beds of gravel, arkose, sand, and clay exposed at many points in the Carolinas and still better displayed at Augusta, Macon, Columbus, and other points in Georgia, and so with the body of like materials stretching from the Chattahoochee to the Tombigbee in Alabama—the Tuscaloosa formation of Smith and Johnson.*

The Potomac formation is now connected, by actual observation of stratigraphic continuity between its most widely diverse phases, and by identification at many intermediate points, from its type locality on the Potomac to and beyond the Tuscaloosa (Warrior). It is indeed variable in structure and materials in different parts of its extent; but the several variations are easily traceable to local conditions of genesis. Viewed in the large way, it is a single and indivisible genetic unit, representing the first episode in the development of the Coastal Plain of the Atlantic and the Gulf with its submarine extension—the first episode in continental growth after the later throes of

* Bulletin U. S. Geol. Survey, No. 43, 1887, p. 105.

Appalachian deformation; it tells of profound depression, pronounced seaward tilting, and prolonged submergence of the young continent, whereby preëxistent physiography was greatly modified, the cis-Mississippi land shrinking to half its area with such attendant climatal changes that the fauna of land and sea was changed and the land flora revolutionized more completely than in any other eon of the earth's history; yet the record of the formation is so readily susceptible of interpretation that, despite the remoteness of the period, and despite the obscurity of later records, it is already possible to map with approximate accuracy the geography of the Potomac epoch. So the formation is a structural and chronologic unit from which the stratigraphy and the geological history of the Coastal Plain may be reckoned.

General Characters and Relations.

As exposed north of Roanoke river, the Appomattox formation consists of moderately regularly stratified sand or clay, with occasional intercalations of fine gravel, commonly of pronounced orange hue, and without fossils so far as known. Farther southward these characters are generally maintained; but local variations appear from place to place, and certain other moderately constant features are displayed.

In eastern-central North Carolina the formation is notably variable and heterogeneous over the thinly covered eastern extension of the Piedmont crystallines now culminating in the continental projection of Cape Hatteras, (which has been during past ages an even more conspicuous geographic feature than to-day); and its features are evidently connected with the proximity of the crystalline strata. Thus, at Wilson there is the usual partition into several regular and rather heavy (2 to 5 feet) strata, the usual orange hue, and the usual distribution of quartzite and quartz pebbles either throughout the several strata or in bands or pockets; but the lowermost stratum exposed in the northern part of town is largely composed of arkose, slightly rearranged and sparsely intermixed with fine quartz pebbles; and there is some admixture of arkose in the superior layers. Then, half a mile south of Wilson, a nine-foot railway cutting displays the usual heavy and moderately regular bedding, and the usual hues both in weathered and unweathered strata; while the lowest exposed bed (4 or 5 feet thick) is made up of inter-laminated gray or white clay and orange or reddish loam, the clay being fine and plastic, the loam rather sandy and massive within each lamina, and the laminæ sensibly horizontal and ranging from an eighth of an inch to half an inch thick for the clay, and quarter of an inch to an inch or more for the loam. Both of these exceptional aspects of the formation are exhibited

in various exposures in this region; both resemble in some measure characteristic aspects of the Potomac formation seen in eastern Virginia; and it is significant that the Potomac is not found here (probably by reason of removal through degradation), that crystalline rocks approach and in the immediate vicinity reach the surface, and so that the Appomattox probably rests immediately upon the eastward extension of the ancient Piedmont crystallines.

Nearer the coast the formation is frequently exposed in railway cuttings and displays the features characteristic of the contemporaneous deposits north of the Roanoke, save that the orange tints are less pronounced and mixed with browns and grays in some strata, that the bedding is thinner and more pronounced, and that pebbles are small and rare. It is significant that the aspect of the formation here approaches that displayed by the phosphate-bearing Pliocene beds of the South Carolina coast.

Another distinctive but hardly distinct aspect of the formation is extensively displayed in central South Carolina, notably about Columbia. Here the usual moderately regular and rather heavy but always inconspicuous bedding of the formation is displayed; but the prevailing colors are richer and darker than in other parts of the terrane, commonly ranging from orange red to chocolate brown. Moreover certain of the strata exhibit a peculiar mottling (which is better displayed farther southward); certain other strata exhibit a distinctive cross stratification defined by gray or white plastic clay in laminæ, irregular sheets, and lines of pellets; the various strata are more uniform in composition than in the north, consisting rather of loam than of sand and clay in alternating beds; and the deposit as a whole takes on a solid, massive, and rock-like appearance, and gives origin to a distinctive topography. So conspicuously diverse in color, texture, and habit of erosion are the prevailing formations of central South Carolina that over thousands of square miles the surface is popularly divided into "red hills" and "sand hills"—the former representing the Appomattox, and the latter the southern interfluvial phase of the Columbia formation. The distribution of pebbles in this vicinity is especially interesting: Northeast of the Congaree river on the line of the Richmond and Danville railway, pebbles are rare to within two miles of the present waterway; there they suddenly increase in abundance, and in some sections within a mile from the river form a considerable and sometimes the principal part of the deposit; while south of the river they quickly become rare, being abundant only within a mile or less of the river bluffs. The pebbles are predominantly of quartz though partly of quartzite, and comprise a

few gneissoid fragments. They range in size from two and a half inches downward. Commonly they are accumulated in lines or pockets, sometimes at the base of the formation; but a few also occur disseminated throughout the ill-defined strata.

About the fall-line on the Santee river system, the Appomattox loam is in part overlain unconformably by the Columbia formation, though it has been severely degraded; and in an admirable section on the Richmond and Danville railway immediately east of the State House, where both upper and lower contacts are displayed, the Appomattox rests unconformably on the Potomac. Further up-river the Appomattox rests directly upon the Piedmont crystallines which here give origin to residuary products of dark red and brown color; and so the origin of the exceptionally rich hues of the formation in this region are not difficult to trace.

Is is in Georgia that the formation appears to be best developed: About the fall-line it stretches from the Savannah to the Chattahoochee in practically unbroken continuity; at many points it overlaps far upon the Piedmont crystallines; on the seaward side of the fall-line it is unquestionably overlapped in turn by the pine clad sands of the Columbia formation over many thousand square miles; it evidently reaches a considerable thickness—perhaps 100 feet or more; and its various features are in part intermediate between and in part common with those displayed by the formation in the Atlantic and Gulf slopes respectively. Moreover it exhibits in this region certain significant features not known elsewhere.

About Augusta, the exposures resemble those of the Congaree, save that the exceptionally rich hues have faded to the usual orange and orange-red; while the cross-stratification marked by lines of clay has become more, and the horizontal bedding even less, conspicuous. There is an excellent exposure of the gravelly loam of the formation at Green's Cut, south of Augusta, on the Georgia Central railroad. It is made up at this point of moderately homogeneous loam with little indication of bedding save that the abundant pebbles are commonly arranged in lines or accumulated in pockets, though sometimes disseminated. Twenty miles farther southward, near Munnerlyn, there is an exposure of 25 feet in which the loam is not only definitely bedded but divided by intercalated layers of sand and silt, giving an appearance of regular and distinct stratification; pebbles being small and rare, while the characteristic orange tints run into dull browns and grays. There is a similar exposure at Sun Hill, sixty miles east of Macon, in which the strata are partially lithified, and the general aspect approaches that of the regularly stratified Tertiary deposits of greater antiquity found farther seaward.

At Macon the formation finds typical development. Above the reach of modern alluvium, and above the vaguely defined and poorly exposed "second bottoms" it forms the prevailing surface; and in every street and suburban road, in every storm-carved runnel and roadside gulley, and in every cutting of the seven railways radiating from the city, its materials are exposed; and the landscapes are toned by its pure orange, orange-yellow and orange-red tints, or the brick-reds assumed on oxidation. Here the stratification of the deposit is rather less definite and regular than usual, and in some limited exposures it is apparently massive. Here, too, the distinctive cross-bedding seen frequently in the south is characteristically displayed—some beds throughout their entire thickness, and nearly all beds in some part of their thickness or length of exposure, exhibit a rather vague cross-stratification rendered conspicuous under certain conditions of weathering by intercalated laminæ and lines of pellets of white or gray plastic clay. About Macon, too, there is well displayed a characteristic habit of erosion and weathering which is common throughout the south and occasionally seen in the north; i. e., the exposed and long weathered surface of the deposit takes on a more massive aspect than that of the fresh cutting, the structure lines fade, the rain-cut gullies are transformed into deep and smooth sided amphitheatres separated by broad, even-faced buttresses: the whole forming soft contours. At the same time the exterior portion of the deposit undergoes a slight cementation, and the surface takes on a sort of dull glaze. This peculiarity of weathering is difficult to intelligibly describe, impossible to clearly portray, and yet so characteristic as to be readily recognizable throughout the greater part of the vast field occupied by the formation. About Macon, as in other exposures near the fall-line and on considerable rivers, the formation abounds in small pebbles, arranged in lines, accumulated in pockets, or disseminated throughout the deposit. On the Oconee these pebbles are chiefly of quartz with many of quartzite, and are commonly well rounded or sub-angular; and it is noteworthy that they are similar in size, material and degree of wear to those found in the subjacent Potomac formation.

At Macon, as at Columbia, the Appomattox is intercalated between the Columbia and Potomac formations, the Piedmont crystallines being exposed beneath the latter in the vicinity. The Columbia is represented by poorly displayed "second bottoms" and by the sand plains into which the lowlands merge a few miles southeast of the city. These deposits are strongly unconformable to and readily distinguished from the distinctive loams of the Appomattox. The Potomac consists

of exceptionally regularly stratified clays and sands, the latter locally containing arkose in considerable quantity, with well rounded pebbles in sheets or pockets and sometimes scattered throughout the mass. It is noteworthy that although the Appomattox and the Potomac are here, as elsewhere, strikingly unconformable, they sometimes merge so completely that no line of demarkation can be drawn with precision. This is frequently the case when the Potomac consists predominantly of sand; when the uppermost stratum consists of clay the contact is usually distinct and sometimes quite conspicuous. In the exposures along the southwestern extension of Fourth avenue the Appomattox and Potomac commonly blend; in the cutting on the Georgia Central railway at the crossing of Oglethorpe street, the formations are readily distinguishable; while in the railway cutting four blocks farther southward the contact is distinct in one part of the section, though the deposits appear to merge in another part.

The finest southern exposures of the three formations so conspicuous and significant in the Middle Atlantic slope are found just below the falls of the Chattahoochee in the villages of Girard and Lively, Alabama, opposite Columbus. As usual there is great unconformity between the "second bottom" loams (by which the Columbia is here represented) and the Appomattox, the latter having been completely removed from a considerable belt flanking the river, while the former rests upon the gneiss and the Potomac arkose throughout a large part of this belt. An analogous relation holds between the Appomattox and the Potomac—an immense volume of the latter having been carried away before the former was laid down.

The characteristics of the Appomattox in this vicinity are normal, save that the distinctive cross-bedding outlined in laminæ of clay or lines of pellets of the same material is exceptionally conspicuous, that the pebbles are larger, more abundant, and rather less worn than usual, and that there is a notable element of arkose in its composition. In explanation of these slight divergences from the type it should be noted that the Potomac in this locality consists in exceptionally large part of arkose (great beds of it sometimes being scarcely distinguishable from the disintegrated gneiss magnificently displayed immediately below the lower dam), that certain layers of it consist of exceptionally pure kaolin-like clay, and that its pebbles are larger and less worn than those found upon smaller rivers—or in short, that the local features of the Potomac are reflected in those of the Appomattox. Contacts between the Appomattox and the Potomac are clearly displayed in the railway cutting in Lively, and in a natural gulley

half a mile northwest of this point; in the former exposure the formations are distinct throughout the greater part of the exposure, but inseparable with any degree of accuracy in another part; while in the second exposure the regularly bedded orange-brown loams of the Appomattox, with a pebble bed at the base, are conspicuously demarked from the creamy-white, cross-stratified arkose of the Potomac. The best exposures of the Appomattox occur in the scarp of a fairly well defined terrace about a hundred feet above the low-water level of the river (below the falls) in the village of Girard.

Eminently satisfactory exposures of the Appomattox occur about Montgomery (particularly in cuttings on the M. & E. railway in the southeastern part of the city), where it rests unconformably upon the Eutaw sands, the junction being sometimes marked by a ferruginous crust, again by a sheet of pebbles, and elsewhere by a decided difference in hue, though it is sometimes indistinct; but the characters of the formation here are in no way specially noteworthy save that the pebbles contain an exceptionally large element of quartzite or semi-quartzitic sandstone, together with large numbers of subangular fragments of chert and siliceous dolomite.

The numerous excellent exposures of the formation about Tuscaloosa are noteworthy in that they form a definite terrace, evidently of considerable antiquity though probably restored in part during the Columbia epoch, upon which the city as well as the State University and Insane Hospital are located. They are also noteworthy in that the pebbles comprise cherts, siliceous dolomites, and a rather unimportant element of quartzite, but no true crystallines. The pebbles are notably smaller and less worn than in the more easterly and northerly localities. Here as elsewhere about the fall-line the formation is overlain unconformably by the Columbia, and in turn overlies with still greater unconformity the Potomac—the Tuscaloosa formation of Smith and Johnson; yet here as in other localities these formations of widely diverse age sometimes merge so completely that no sharp line of demarkation may be drawn between them. This is notably the case in the railway cutting at Cottondale, seven miles east of Tuscaloosa, where the Potomac is a cross-stratified gravel with a matrix of sand, and the Appomattox a horizontally bedded mass of similar gravel in a matrix of loam; yet usually despite this discordant bedding, the materials merge. In some of the cuttings on the A. G. S. railway between Cottondale and Tuscaloosa, however, the junction is marked either by ferruginous crusts or by sheets of pebbles of ferruginous sandstone evidently derived from the older formation.

Farther southward the formation is displayed at several

localities, notably at Eutaw. Here it diverges from the usual character in two respects, each of which indicates an intimate relation to a subjacent and much older formation: north and east of Eutaw the deposit is exceptionally sandy and friable and the bedding is frequently obscure; and in numerous exposures on the A. G. S. railway and along the wagon road between Eutaw and the Tuscaloosa or Warrior river it may be seen to merge into the stratified sands of the Eutaw, and in general to take on the features of that Cretaceous formation;—in short it is as evident here that the Appomattox is made up in part of the immediately subjacent formation as it is in the numerous contacts with the Potomac (Tuscaloosa) formation at Lively, Macon, Columbia, and other points at which the materials obviously intergraduate. Southwest of Eutaw a change in the composition and general behavior of the deposit quickly supervenes; only scattered ridges and irregular patches of the formation now remain overlying the peculiar middle Cretaceous formation which Smith and Johnson now designate the Tombigbee chalk (the "Rotten Limestone" of the books); in these outliers the deposit exhibits the usual characteristic features of the deposit; but on close examination the sands and clays of which it elsewhere consists are found to be intermixed with calcareous particles, while toward the surfaces it loses the peculiar massive aspect and dull glaze so commonly characteristic of the formation, and commonly breaks down into sandy red clays. Over the Tombigbee chalk in this vicinity the prevailing colors are lighter and grayer, and over the Eutaw sands darker and browner, than those displayed toward the fall-line or generally elsewhere.

It is in Alabama that the Appomattox formation has been found nearest the coast: between St. Elmo and Grand Bay, in the extreme southwestern corner of the state, two strongly contrasted types of surface appear. The first comprises the smooth, sensibly horizontal pine-clad sands or "pine meadows" of the coast; and the second consists of undulating bosses, knolls, and plateaus rising above and evidently protruding through the sand. The sand plains and pine meadows represent the local phase of the Columbia formation; while the protruding knolls and plateaus of ancient topography consist of regularly and rather heavily bedded loams, sands, and clays, commonly orange-hued but weathering to dark reds and browns, and evidently represent a somewhat erratic phase of the Appomattox. The deposits are erratic, *first*, in the complete assortment of materials, the sands and clays being separated and laid down in alterating layers; *second*, in the fineness of the materials, clay forming the predominant element and the pebbles being represented only by bits of quartzite or chert seldom over a

quarter of an inch in diameter sparsely disseminated through the sandy layers; *third*, in the exceptionally regular stratification; and *fourth*, in the absence of the distinctive clay-outlined cross stratification—though the sandy strata are sometimes cross bedded. The formation here is exceptionally ferruginous. A thin layer in a cutting three-quarters of a mile east of Grand Bay is locally used as an ochre; the plowed fields and other exposed surfaces are sometimes besprinkled or even shingled with small ferruginous nodules (or "buckshot") weathered out of the loam; the prevailing colors are harsher and generally darker than usual (though not so dark as at Columbia), ranging from orange-yellow mixed with gray in some strata, to prevailing orange-reds weathering to brick-reds and chocolate-browns; and the peculiar mottling characteristic of the deposit under certain conditions of exposure throughout nearly its whole extent is beautifully displayed. In the railway section in the eastern part of Grand Bay the relation between the mottling below the reach of ready oxidation and the formation of the ferruginous concretions found on the surface are clearly shown: the lower part of the exposure, extending to within 10 or 12 feet of the surface, is of fairly uniform orange or orange-yellow hue, with some strata passing into gray; next follows a stratum of 5 or 6 feet, concentric with the surface and discordant with the stratification, in which the uniform hues are shot with vertical or oblique lines of darker color, increasing in number upward and finally uniting in a network of orange-red bands an inch or more in width enmeshing polygons and irregular figures of original color one to five inches in diameter; while still nearer the surface the bands widen, the lighter colored polygons disappear, and a nearly uniform orange-red hue supervenes. Yet some of the lines of darker color persist as narrow bands of brown, perhaps marking jointage planes; and on closely approaching the surface these are frequently found to become partially indurated, so as to form a network of embossed chocolate-brown lines, enmeshing orange-red polygons. About the points of union of the embossed brown bands the segregation of ferruginous matter and the cementation are most decided; and quite near to the surface the nuclei thus formed may be found to graduate into irregular ferruginous nodules, diminishing in size and increasing in hardness until they pass gradually into the state exhibited by the surface-found concretions. So the mottling, the darkening of hue, the general ferrugination, and the formation of nodules are simple results of oxidation and hydration produced by weathering.

In Mississippi the Appomattox is well displayed at Nicholson, near Pearl river, and only 20 miles from the Gulf; and 10

miles farther northward, at Highland, there is a still better development in which there is so large an element of pebbles that the deposit has been extensively worked as a source of gravel for railway ballasting. At these localities the formation exhibits the usual characteristics, save that in the first pebbles are small and rare. In the second locality the abundant pebbles consist predominantly of sub-angular fragments of chert an inch and a half or less in diameter, with no representatives either of the quartz and quartzite of the northeast, or of the siliceous dolomite found at Tuscaloosa. At Hattiesburg the formation is exposed in the uplands overlooking Leaf river, and about Ellisville it crosses the divide between that river and the Tallahoma, the usual characteristics being displayed in both localities; at Vossburg there is an extensive accumulation of the deposit, which is here fairly stratified and exceptionally friable, on the divide between the Leaf and Chickasawhay drainage basins; and at Brandon the exposures are less extensive than but similar to those at Vossburg.

In the vicinity of Meridian there are numerous exposures, some of which are erratic in character: Over the ridge formed by the peculiar siliceous rocks of Eocene age called by Smith the Choctaw buhrstone, the Appomattox is uncommonly obdurate, and the distinct cross-bedding is outlined in fine sand rather than in clay: yet despite the uncommon obduracy of the material it has been completely removed from the greater part of the surface throughout much of this belt of high relief. On the northeastern side of the isolated knob of Buhrstone a mile south of Meridian there is a bed of brown or orange-red sand corresponding in many respects with, and probably justly referable to, the Appomattox, though the usual heavy bedding is absent, the characteristic cross-bedding is inconspicuous, and the mass is much more friable than usual. On the lowlying lands three miles northeast of Meridian the Appomattox generally forms the surface; but it here contains an exceptional element of clay, and in many sections appears to merge into the Eocene clays assigned to the Hatchetigbee formation by Smith and Johnson, just as another phase merges into the Potomac (Tuscaloosa) in another locality.

So the Appomattox formation may be briefly described as a series of obscurely stratified and frequently cross-bedded loams, clays, and sands of prevailing orange hues, with local accumulations of gravel about waterways; the materials varying somewhat from place to place, but always in the direction of community of material between the formation and the older deposits upon which it lies; while as a whole the deposit retains so distinctive and strongly individualized characteristics as to be readily recognized wherever seen.

Geographic Distribution.

The areal distribution of the Appomattox formation may be stated either simply and easily in terms of original deposition, or in greater detail and with more difficulty in terms of present outcrops.

In general distribution, the formation is known to expand and thicken southward from a few thin beds occupying a narrow belt on Potomac creek, a few miles north of the Rappahannock, to a thick deposit forming a terrane forty or fifty miles wide on the Roanoke; to extend thence southward, in a broad zone at first widening but afterward narrowing with the encroachment of the overlapping coast sands upon its area, quite across the Carolinas; to form the most conspicuous terrane of central Georgia, where it stretches from the fall-line to the inland margin of the coast sands all the way from the Savannah to the Chattahoochee; to again expand greatly in Alabama with the contraction of the overlying coast sands until it forms an essentially continuous terrane stretching from the fall-line at Montgomery and Tuscaloosa to within half a dozen miles of the Gulf in the southwestern corner of the state; and to maintain this enormous width in Mississippi, where it extends southward from the Paleozoic area in the extreme northeastern corner of the state to within twenty miles of the Gulf on Pearl River and westward to within fifty miles of the Mississippi, to be in part overlain and in part replaced by the local phases of the more recent Columbia formation developed on Gulf and river. This field of fully 50,000 square miles is that over which the Appomattox has been traced in thousands of exposures, and in which it generally forms the prevailing terrane.

If the direct observation be supplemented by legitimate and necessary inference, the formation must be so extended as to bridge the valleys from which it has been degraded, and to stretch beneath the various phases of the Columbia formation well toward the Atlantic and Gulf coasts—though its seaward extension is doubtless aberrant in composition and structure, particularly in Florida, where it merges with the continuous series of off-shore deposits of the Neozoic which combine to form the great submarine shelf fringing the continent on the east and south. With this legitimate extension, the field of the formation becomes essentially coëxtensive with the Coastal Plain of the Atlantic and Eastern Gulf slopes (exclusive of a part of Florida) and assumes an area of 250,000 or 300,000 square miles. Over the whole of this vast area the Appomattox formation must have stretched; and over the greater part of this area it must maintain the wonderfully uniform characteristics of composition and structure exhibited to-day by its stream-carved remnants.

The areal distribution of the remnants of the Appomattox formation represented by present exposures cannot be set forth in detail without large scale maps or more elaborate statement than space will now permit; but certain features of local distribution are too significant to be neglected.

Throughout the Coastal Plain the formation is deeply dissected if not completely divided by the larger rivers at and commonly for long distances below its inland margin. The tributaries have invaded it as well, and so too have the smaller streams, down to the rivulet and storm-filled rill; and thus its entire surface has been sculptured by running water in a manner well illustrating the type of configuration elsewhere classed as autogenetic. Now many of the tributaries, as well as some of the subordinate members of the wide branching drainage systems, have, like the principal rivers, cut completely through the formation and exposed the sub-terrane over considerable areas; and while the extent of the destruction of the formation in this manner is of course dependent upon the local efficiency of the several factors of degradation (declivity, stream-volume, texture of the rock mass, etc.), it is evidently related in some degree to the character of the subterrane. This relation is well exemplified over the uplands flanking the Tombigbee and Alabama rivers on the west. Over the terrane of the Potomac formation the Appomattox generally prevails, despite the considerable altitude and high local relief, save in the valleys of the largest rivers; over the less elevated terrane of the Eutaw sands, it is more frequently and more widely cleft by drainage ways, and its remnants are thinner; over the next newer formation (the Tombigbee chalk) which lies low and flat, the greater part of the Appomattox has been carried away, not only in the vicinity of the Tombigbee river but all the way from northeastern Mississippi to beyond the Alabama river, so that it is commonly represented only by isolated belts and irregular patches which, as Smith has shown, most frequently lie on northerly slopes; over the terrane of the Eufala sands, in which the local relief again increases, the remnants of the Appomattox quickly increase in number and expand until the formation once more forms the prevailing surface on the uplands, though the Cretaceous deposits are laid bare along most streams and form the prevailing lowlands; and over the eight or nine lower Eocene formations into which the Lignitic of Hilgard has been divided by Smith and Johnson, and among which clay is the predominant material, the Appomattox still further expands until it forms almost the entire surface, highland and lowland alike, save in the valleys of the larger rivers. Still farther southward lies the great siliceous deposit of the middle Eocene

commonly known as Buhrstone—the Choctaw buhrstone of Smith; its rocks are the most obdurate of the entire Neozoic series within the Gulf slope, and so its general surface is elevated and sculptured into a complex configuration of pronounced relief and sharp contours; yet despite these conditions so exceptionally favorable to degradation, the Appomattox frequently maintains its integrity over considerable areas. Beyond the hill-land of the buhrstone lies the lowland formed by the predominantly calcareous newer Eocene formations—the Claiborne, Jackson and Vicksburg—over which the Appomattox is again trenched by almost every waterway and reduced to ragged remnants only more extensive than those overlying the Tombigbee chalk; but upon the silico-argillaceous terrane of the Grand Gulf the remnants once more expand until they form the greater part of the surface, save along the larger waterways, as about Hattiesburg in Central Mississippi. In short, the formation is generally preserved over loamy and clayey terranes, much more seriously invaded by erosion over sandy terranes, and largely degraded over calcareous terranes; and this is true not only of the section from Tuscaloosa to Hattiesburg in Alabama and Mississippi, but of the formation as a whole.

It has already been intimated that the composition of the Appomattox everywhere depends in part upon that of the subterrane, i. e., that its materials everywhere consist of local elements and erratic elements combined in varying proportions; and the variable friability and solubility resulting from this inequality in composition is evidently the reason for the unequal resistance which the formation has offered to degradation in various parts of its extent.

Hypsographic Distribution.

The best development of the formation in Virginia and North Carolina lies between 25 and 150 feet, and its upper limit is probably less than 250 feet, above tide. Farther southward the lower observed limit remains about the same, while the upper rises to at least 650 feet over the divide between the Congaree and Savannah, where the formation is well developed and constitutes the prevailing surface. The lowest altitudes at which it has been observed near the Gulf are less than 25 feet above tide at Nicholson and not much higher at Grand Bay; and the greater altitudes in the Gulf slope are not less than 450 feet in uplands near Tuscaloosa, and 600 feet in the Buhrstone hill-lands west of Meridian.*

*It has recently been found washed by tide waters on the east side of Mobile bay, by Mr. L. C. Johnson.

Briefly, the hypsographic distribution of the Appomattox formation is essentially identical with that of the general surface of the Coastal Plain from the Potomac to the Pearl, save that the formation extends a little farther inland than the mass of the Neozoics, overlapping for a few miles of distance and a few yards of altitude upon the Piedmont crystallines within the fall-line.

Stratigraphic Relations.

In several exposures on the Appomattox river at and below Petersburg, the fluvial phase of the Columbia formation (as developed in the Middle Atlantic slope) rests unconformably on the surface of the Appomattox, and a like relation to the inter-fluvial phase is displayed in several railway cuttings south of Petersburg. In the excellent section at Columbia the coast sand phase of the Pleistocene formation rests unconformably upon the Appomattox; and at Lively, Alabama, the "second bottom" phase of the newer formation overlaps unconformably an eroded surface of the older one. From these exposures in section the two formations are known to be diverse in age.

The unconformity between the Columbia and the Appomattox becomes more striking when the relations of the two formations to the larger rivers are considered: Every great waterway traversing the Coastal Plain from the fall-line to the shore of Ocean or Gulf has for scores of miles trenched the Appomattox to its base and commonly cut far into older strata, and the orange loams and sands are usually removed from the bottom and half the sides of the trough whose axis is marked by the waterway; while the same rivers are flanked by terraced belts of Columbia loam overlying the degraded edges of the Appomattox and the older strata alike, and little invaded by erosion (except on the Savannah and the Congaree) save that of the river channel. It is true that the Chattahoochee, Tuscaloosa or Warrior, and some other rivers are locally flanked by terraces of Appomattox materials; but these terraces appear to be the product of local wave work during the Columbia submergence rather than of the rivers and waves of the Appomattox period.

Still more striking does the unconformity appear when the general configuration of the two formations is compared: About Grand Bay and St. Elmo in southwestern Alabama the Columbia forms a smooth, monotonous, sensibly horizontal plain, while the knolls and uplands of Appomattox protruding through the flat-lying sands exhibit well developed autogenetic sculpture; over the smooth plains of the Tombigbee chalk the Columbia deposits skirt the rivers in sharp-cut terraces, while

the Appomattox has been largely removed by erosion; on the Oconee and Ogeechee Rivers in eastern-central Georgia the monotonous plains formed by the coast sands of the Columbia encroach upon and send tongues and fingers into the ravines and broader depressions of a boldly sculptured upland of Appomattox loam; and in North Carolina and Virginia the Columbia is little more than a flowing mantle masking the more rugged framework of the older Appomattox. Indeed, throughout their extent these formations illustrate the contrast between "topographic youth" and "topographic old age" as defined by Chamberlin—the one is soft faced, smooth, nearly featureless; the other hard-visaged, furrowed, strong featured.

Local unconformities between the Appomattox and the several subjacent Neozoic formations are frequently exposed in section; and general unconformity with all these formations alike is indicated by its overlap upon all from the Grand Gulf of the Miocene to the Potomac (Tuscaloosa) of the Cretaceous or Jurassic.

Especially significant is the unconformity between the Appomattox and the Grand Gulf—the youngest of the series: In southern Mississippi generally, and notably in the vicinity of the Tallahoma river about Ellisville, there are sufficiently numerous exposures of the siliceous clays constituting the Grand Gulf to show that the surface of the terrane is one of autogenetic sculpture, that the Appomattox was laid down as a continuous mantle upon this sculptured surface, and that after the close of the Appomattox period the rivers resumed approximately their ancient courses and have impressed a new and fairly consistent sculpture upon the old. So, while the newer formation crowns eminences and floors depressions alike where not profoundly eroded, its mass is little if any thicker on the upland than in the valley, and exposures are as common in the upper as in the lower slopes; and along the larger rivers the Appomattox has been frequently removed from the lower slopes while it yet crowns the divides and highlands quite to the brows of the bluffs.

Especially significant, too, is the relation between the Appomattox and the obdurate strata of the Choctaw buhrstone, since a rough record of great continental oscillation is contained therein: Southwest of Meridian and west of Corinne lies a prominent ridge of the peculiar siliceous rocks of this formation, making the divide between the Okatibbee and Chunkee river. This divide is a meandering crest, sending out lateral spurs and culminating in height at every bend, separating a plexus of steep sided ravines, coves and amphithe-

aters—the whole simulating a mountain crest-line with its peaks, arêtes, cols, gorges and amphitheaters, save that every summit is blunted. This striking configuration tells a significant story, but one too long for repetition here—it suffices that it tells of a time when the land stood higher and the rivers were made more energetic than to-day. Now over this irregular surface the Appomattox was evidently spread mantlewise, just as over the qualitatively similar though less strikingly emphasized surface of the Grand Gulf; and here as there the post-Appomattox rivers sought their old courses, and the new drainage system corresponds substantially with the old;* but the lower base level of to-day has tended to develop a flatter surface than the old, and while remnants of the orange loam are frequently caught on the crests and lodged in the amphitheaters, they have been commonly removed from the higher altitudes and are generally confined to the lower levels.

Perhaps the Appomattox merges into the phosphate-bearing Pliocene beds of South Carolina; probably it is continuous with some of the newer off-shore deposits of Florida; unquestionably it represents but the landward portion of one of a vast series of deposits which at some distance beyond the present shores of Ocean and Gulf are unbroken; but certainly there is a great unconformity, first between the Pleistocene Columbia and the Appomattox, and second between the Appomattox and all of the subjacent Neozoic formations yet satisfactorily discriminated within the Atlantic and Gulf Slopes.

Taxonomy.

No fossils have thus far been found in the Appomattox formation except at Meridian, where Johnson has found it to contain well preserved magnolia leaves apparently identical with those of trees now growing in the same vicinity. Its stratigraphic position, unconformably below the Pleistocene and unconformably above the (probably) Miocene Grand Gulf formation, indicates an age corresponding at least roughly with the Pliocene.

The formation represents a considerable part of a more or less vaguely defined series of deposits variously called "Orange Sand," "Drift" or "Quaternary," "Southern Drift," etc., by many geologists; but since this vaguely defined series included

* The history of renewal of buried drainage systems in the eastern Gulf slope is recorded in wonderful fulness and clearness. Three and even four times has the autogenetically sculptured surface of the Choctaw buhrstone been submerged and mantled with sediments, only to rise and resume more or less fully its old aspect under the influence of waterways following the old lines. Such resurrected, or *palingenetic*, drainage and sculpture is characteristic of much of Mississippi.

not only the Appomattox but also the basal gravel beds of the Pleistocene loess, parts at least of the Cretaceous or Jurassic Potomac (Tuscaloosa) formation, and other deposits of various ages, none of the old designations can be retained without material modification in definition. It therefore seems wise to extend the term applied to the formation in the region in which it was first studied and clearly defined.

Sources of Materials.

The materials of the formation which may be certainly traced to their sources are (1) pebbles or gravel, (2) arkose, and (3) a certain portion of the more finely divided matter.

It has been stated incidentally that about the fall-line the pebbles of the Appomattox are in large part identical with those of the Potomac, and that they are evidently derived therefrom. It has also been stated incidentally that the pebbles of both Appomattox and Potomac vary from river to river —quartz on the Rappahannock, quartzite with less quartz on the James and Appomattox, quartz with less quartzite on the Roanoke, quartz mainly on the Neuse and Cape Fear, quartz with less quartzite on the Santee system, quartz and quartzite in nearly equal proportions on the Savannah and Ocmulgee, quartzite with less quartz on the Chattahoochee, quartzite, siliceous dolomite, quartz, and chert (in order of abundance) on the Alabama, siliceous dolomite, chert, and quartzite on the Tuscaloosa (or Warrior), and chert on the Pascagoula and Pearl; and this variation goes exactly with the petrographic character of the most obdurate rocks traversed by the upper reaches of the respective rivers.

Arkose is but a limited and unusual constituent of the formation, and is only known to occur under two sets of conditions: It occurs when the formation rests directly upon crystalline rocks or when these rocks are exposed in such proximity as to indicate absence of deposits intermediate in age, as at Wilson, N. C. It occurs also, in less abundance and purity, where the Appomattox rests directly upon the Potomac formation and the latter is made up largely or exclusively of the same material, as at Girard, Alabama. In both cases the material is evidently derived from an adjacent and older formation.

Certain striking features in geographic distribution of the Appomattox formation already pointed out indicate that in many if not in all cases a part of its materials were derived from immediately subjacent strata, and so that the character of this formation in a measure reflects that of the sub-terrane—the characteristic orange loams being exceptionally loamy over

loams, exceptionally sandy over sands, exceptionally argillaceous over clays, and exceptionally calcareous over limestones.

The combined volume of pebbles and gravel, arkose, and the local elements of finely divided material, however, constitute but the smaller portion of the entire bulk of the formation; and the general similarity in composition of the formation with the residuary loams and clays both of the Piedmont crystallines and of the Paleozoics of the Gulf slope suggests that these residua contributed largely to the formation. This suggestion gains strength from the phenomena exhibited at Columbia, where the Appomattox takes on a local aspect corresponding precisely with the local aspect of the residua derived from the neighboring crystalline rocks.

Interpretation.

The Appomattox formation illustrates a method of geologic correlation which has grown out of the work in the Coastal Plain of eastern America, and which is deemed worthy of statement.

The primitive method of geologic correlation depends upon tracing actual stratigraphic continuity across or around intervening areas. This method is to-day the simplest and safest within the reach of geologists; but it is practicable only within single geologic provinces, and is limited by many other conditions.

Another method of geologic correlation is based upon petrography. At certain stages in the development of the science of the earth, the various classes of rocks have been more or less widely correlated upon grounds of similarity in composition, texture, structure and other petrographic characters; but it is now generally recognized that these characters are simply the expression of processes and conditions which have been repeated in many parts of the world and in all periods, and thus that the method can only be applied cautiously and within narrow limits. To-day, correlation by petrography is practically confined to the ancient crystalline rocks, and even here it is viewed with distrust by leading American students.

The disciples of William Smith—who are as numerous to-day as the devotees of geology—correlate groups of rocks by paleontology. It is the strength of this method of correlation that, as practically applied, it embraces the desirable features of the more primitive methods; that it involves also a broader and more comprehensive grasp of phenomena and principles than the simpler methods out of which it was developed; that it rests upon a sound philosophic basis; and that it unites the

physical aspect of geology with the record of biotic development upon the earth in such manner as to form a logical and consistent basis for the current cosmogony of enlightened men. It is the weakness of the method that many rocks are too poor in fossils to be correlated thereby; that formations may be homotaxial yet not contemporaneous and *vice versa;* that fossil facies represent the product of two principal factors of which one (environment) is so variable under local conditions that the product is inconstant among the minor rock divisions; and that the geologic chronometers afforded by fossil plants, fossil invertebrates and fossil vertebrates respectively give unlike time units and, sometimes, discordant readings. To-day the larger groups are confidently correlated by paleontology; but leading American geologists no longer accept identity of fossil facies as final proof of equivalence among the minor rock divisions.

The method of correlation devised to systemize the structure of the Coastal Plain combines the desirable features of the older methods, and adds thereto the interpretation of the products of the several physical processes operating upon the earth's exterior. It is a correlation by community of genesis, or *homogeny*. The method involves a yet broader conspectus of phenomena and principles than the paleontologic method; for in its application it is necessary to mentally restore the various physical and biotic conditions of the past, just as paleontology vivifies the fossils of past ages.

Correlation by homogeny is a simple application of the well known principles (1) that geologic processes may be inferred from their products, and (2) that geologic processes are universally interrelated.

Since the birth of the science it has been the proximate end of geology to ascertain the genesis of terrestrial phenomena, with a view to the ultimate end of developing a rational and valid cosmogony; and great progress has been made in this direction. Now, "scientific progress may be measured by advance in the classification of phenomena. The primitive classification is based on external appearances, and is a classification by analogies; a higher classification is based on internal as well as external characters, and is a classification by homologies; but the ultimate classification expresses the relations of the phenomena classified to all other known phenomena, and is commonly a classification by genesis." So, the primary geologic classification was based directly upon the objective phenomena of the external earth, and early geologic literature was pervaded and the science shaped by this fundamental idea. As time went on this classification was found too narrow to

represent intelligibly the facts and their relations, and the desire for a more comprehensive taxonomy was indicated by semi-arbitrary division of the science into departments defined by community of agencies (physical geology, structural geology, historical geology, etc.), within which the minor classes were variously defined and grouped. Still later, not only the primary but the secondary categories of phenomena came to be commonly defined by genesis; and to-day the taxonomy adopted by leading American geologists is predominantly genetic, and geologic research is considered incomplete if it fails to indicate the origin and course of development of the phenomena studied.

The interrelation of geologic processes is illustrated in terrestrial gradation—the matter degraded from one spot or region is deposited in some other spot or region; and commonly the regions of degradation and deposition are contiguous. It is also illustrated in the deformation of the terrestrial crust, whether antecedent or consequent*—when one part of the terrestrial crust is heaved another part is thrown; and commonly the heaved and thrown parts are contiguous. It is illustrated moreover in the relations between deformation and gradation—when a mountain range or a continent is lifted it is attacked by degradation, and when a sea bottom is formed it is subjected to deposition; and when degradation lightens the continent or mountain it is still further lifted, and when deposition loads the sea bottom it is still further depressed. This interrelation runs through the entire range of geologic processes. It follows that any process operating in one part of a geologic province must be represented by a similar or kindred process in other parts of the same province—i. e., in a mountain province the degradation of one part is represented by degradation (perhaps at different rates) in all parts; and in a sea province deposition in one part is represented by deposition (varying in rate and quality with local conditions) in all other parts. It equally follows that the products of the processes are genetically related—that the sculptured forms produced by degradation are of common genesis and greater or less similarity in form according to the local conditions, and that the deposited beds are of common genesis and greater or less similarity in volume and material according to the local conditions. It further fol-

* The various mass movements concerned in the development of continents and mountains are conveniently grouped as *deformation*, and the various classes of particle movements concerned in the transfer of materials upon the surface by air, water, ice, and other agencies are conveniently grouped as *gradation;* the earth movements concerned in the elevation and exposure to degradation of continents are conveniently classed as *antecedent;* and the earth movements resulting from transfer of materials through the processes of gradation are conveniently classed as *consequent.*—Cf., Nat. Geog. Mag., vol. i, 1888, pp. 27–36; Geol. Mag. Decade III, vol. iii, 1888, pp. 489–495.

lows that the sculptured forms on the one hand are genetically related to the deposited beds on the other hand; and it is indicated not only by theory but by observation that such relations sometimes extend not only from land province to sea province, or *vice versa*, but across a sea province from one to the other of the land provinces by which it is bounded, or *vice versa*, and thus throughout great areas and perhaps continents. In short, it is evident that when geologic agency was at work in any spot it must have been doing something throughout the neighborhood; and properly conducted field work commonly shows what this something was.

Now the universal interrelation of geologic processes has been constantly recognized in the researches into the genesis (1) of the deposits forming the Coastal Plain and (2) of the correlative sculptured forms found in the contiguous Piedmont and Appalachian regions; and it has been ascertained that each category of phenomena commonly represents two classes of genetic conditions—one general and the other local. Thus the topography of the Piedmont and Appalachian regions gives a record of a certain elevation above base level during each of three or four well defined periods, as a general condition whose effects may be traced over immense areas; but it also gives a record of local conditions varying from place to place with the volume and declivity of streams, the obduracy of the rocks, the strike and dip of the strata, the homogeneity or heterogeneity of the terranes, etc. Thus, too, the sedimentary formations of the Coastal Plain give a record of submergence beneath the ocean, during each of several well defined periods, as a general condition affecting immense areas; but they also give records of local conditions varying from place to place with the proximity to and volume of rivers, the exposure to prevailing winds, waves, and currents, the depth of submergence, the proximity to shores, etc. But the effects of the general and local conditions respectively can commonly be discriminated with confidence, and the products of the general conditions traced throughout their extent. This is true specifically of the littoral and marine formations of the Coastal Plain, all of which represent widespread submergence with local variations in depth of water, proximity to shores, activity of deposition, vicinity of rivers, activity of waves, etc. The Coastal Plain formations may therefore vary from place to place in composition, texture, and structure; but the different phases are intergradnating parts of an indivisible unit, the local variations are repeated from place to place, and the attitude of each formation indicates a like relation between sea and land in all parts.

In discriminating the general and local genetic conditions, it is necessary to ascertain the relations between each formation

and its newer and older neighbors, and to interpret the record of each unconformity in terms of continent growth. By this means the different parts of a formation may be found to represent not only general community of genesis but community of beginning and ending—in short entire community of structural relation. Each part of the formation then records in similar terms the same episode in continent-building and world-growth.

So, when a Coastal Plain formation is found to represent general community of genesis and structural relation in its various parts it is considered homogenic and accepted as a record of an episode in geologic history. The parts may or may not be homotaxial; one part may be slightly older than another part; but in a general way it is contemporaneous throughout. Homogeny implies not only equivalence but synchrony.

The value of homogenic correlation is illustrated by the Columbia formation: in the Middle Atlantic Slope the formation consists of two diverse phases, one of which is composed of dissimilar parts; in the Southern Atlantic and Eastern Gulf slopes the brick clays, bowlder beds, and veneers of local debris of the north are replaced by the "second bottoms" and coast sands; and in the Mississippi embayment the formation is represented by the stratified clays, silts, and sands of the Port Hudson, and the strongly individualized loess with its basal gravel beds. Yet these widely diverse deposits represent a general condition of submergence varying in amount from region to region, in a gradual manner; the basal unconformities are alike, and represent like conditions of continent-growth; and the degradation suffered by the formation in its various parts is indicative of like antiquity. Again, one local phase found in the Middle Atlantic Slope tells of local activity of the rivers, the other tells of a general activity of estuarine waves and currents, and both tell of glacial cold; the testimony of glacial cold fails in the Southern Atlantic and Eastern Gulf slopes, but there one phase tells of river work and estuarine conditions, and another of wave work and marine conditions, both operating on a distinctive local formation. So, too, the loess and the subjacent gravel beds in the Mississippi embayment tell of glacial cold in the upper reaches of the river, accompanied first by a stimulated transportation and subsequently by such submergence as to slacken the waters and precipitate fine debris; while the Port Hudson clays, silts, and sands tell of submergence and estuarine deposition in the brackish waters of an arm of the Gulf. Thus the general condition represented by the deposit is everywhere the same; while the local variations may be ascribed to varying local con-

ditions. The formation has indeed been connected stratigraphically between its most widely diverse phases and throughout a considerable part of its area; but the absolute identification of the various parts of a formation so diverse in composition, so vast in area, and so unequal in hypsographic distribution, is rendered possible and satisfactory only by the homogenic method of correlation.

The value of the method is still better illustrated by the Appomattox: This formation is frequently buried beneath newer deposits, and frequently and widely divided by erosion over large areas, so that connection of the exposures by stratigraphic continuity is impracticable. It is essentially unfossiliferous in the exposures thus far examined, so that paleontologic correlation is impracticable; and while its materials, texture and structure are moderately constant, they are too variable to warrant correlation by petrography alone. Yet it is evident that the various parts of the formation are littoral or sub-littoral; that all represent temporary incursion of the sea upon a long-sculptured land surface; that all are affected by the composition of the subterrane; that all are affected by the proximity of rivers flowing along the present water lines; that the materials everywhere comprise certain constant elements; and that the structural relations of the formation are essentially identical throughout its extent. So this formation, like the Columbia, tells of a uniform general condition and of certain easily discriminated local conditions; and its various parts may thus be confidently correlated by homogeny. The formation has indeed been traced and connected as far as possible by stratigraphic continuity through thousands of exposures; but the isolated knobs projecting through newer deposits and the isolated remnants left by erosion, and indeed the regional developments of the orange-hued deposit could never have been satisfactorily identified save by homogeny.

Eventually the formation will be confidently correlated with certain topographic stages displayed in the Piedmont and Appalachian regions of the Southern Atlantic and Eastern Gulf slopes; but this correlation remains for fuller development through future work.

It should be pointed out that neither the Columbia nor the Appomattox adequately illustrates the value of homogenic correlation, by reason of their poverty in fossils. Thus far paleontologic correlation has been based upon certain explicit or implicit assumptions concerning the geographic distribution of organisms and the relations between organisms and environment during past ages; i. e., it has been commonly assumed by paleontologists that the geographic distribution of organisms and their relations to environmental conditions in the past were much the same as those of the present. But when the

geologic formations are correlated by the physical method, the geographic distribution of organisms and the relations between organisms and environment during the geologic periods may be determined with only less accuracy than the like conditions are determined to-day. So, by homogenic correlation, the ebb and flow in the many branches of the vital stream during long past eons will be measured, homotaxis will blend with homogeny, and the cosmogony which it is the province of geology to develop will be refined and ennobled.

By reason of its prevalence, its distinctive coloration, and its fairly homogeneous composition, the Appomattox formation is the most conspicuous deposit of the Coastal Plain between the Roanoke and the Mississippi; over much of this vast area it has been traced in thousands of exposures and extensively connected by stratigraphic continuity, yet the observations have been fully interpreted and the exposures finally correlated by homogeny; and it is largely through the application of this method of study that the formation has been found to be a well defined and indivisible structural unit, representing a single clearly defined episode in the development of the continent. So distinctive is the orange-hued loam, and so definite the history recorded within it, that it is destined to rank as a great datum formation, from which the stratigraphy and geologic history of the Coastal Plain must be reckoned downward and backward as they are reckoned upward and forward from the Potomac.

Hitherto no geologist has been able to form a definite conception of the physiography of the southeastern part of the continent during any given period. The episodes were too short and the distances too long to permit satisfactory paleontologic correlation; the deposits vary from state to state, and from Gulf province to Atlantic province; beds come in and beds run out; limestones change to shale and shales to sandstone; with the changes in material there are changes in fossils, and the complex history recorded in the everchanging series has never been raveled; and not half the total thickness of the beds yields faunæ or floræ in sufficient wealth for close chronologic identification. Geologists have indeed formed general conceptions of the development of the province; but they have been hazy in detail, shadowy with respect to the succession of events, and vague with respect to quantitative measures of time or deposit. But the Appomattox formation, with the method of homogenic correlation which it largely inspired, enables the student to represent graphically and with fair accuracy the physiography of the southeastern part of the continent during a well defined episode.

ART. III.—*An experimental proof of Ohm's Law: preceded by a short account of the discovery and subsequent verification of the law;* by ALFRED M. MAYER.

I PURPOSE giving in this paper a simple and direct experimental proof of Ohm's law, $\left(C=\frac{E}{R}\right)$. Generally a mere formal statement of this law with illustrations are given in text books on Physics, and the student is left to infer that its truth is shown by the cumulative evidence given by the immense number of quantitative relations in electrical actions which the law associates, and by the experience that deductions made on the basis of this law agree in measure with the results of experiments. The latter fact is certainly one of the best proofs of the truth of the law; but, nevertheless, the relations between C, E and R are not directly and simultaneously shown to be exactly expressed by $C=\frac{E}{R}$. It is true that some works give experiments to show this relation but they are so difficult to perform by reason of the difficulty of maintaining constant C, E and R, that the results of the experiments only approximate to those required by the law.

Ohm was led to the conception of this law by *assuming* that the flow of electricity in a voltaic circuit is similar to the flow of heat by conduction in a rod of indefinite extent. Also, his assumptions that the actions of two electrified particles are directly as their distance and that the electricity is uniformly dense over each cross section of a conducting wire were directly opposed to the laws and facts well established by Coulomb for statical electricity. It is not surprising that scientific men were slow in adopting the views and theory of Ohm. In his memoir (Die Galvanische Kette mathematisch bearbitet von Dr. G. S. Ohm: Berlin, 1827), he states:* "Three laws, of which the first expresses the mode of distribution of the electricity within one and the same body, the second the mode of dispersion of the electricity in the surrounding atmosphere, and the third the mode of appearance of the electricity at the place of contact of two heterogeneous bodies, form the basis of the entire memoir, and at the same time contain everything that does not lay claim to being completely established. The two latter are purely experimental laws; but the first, from its nature, is, at least partly theoretical.

* See translation, published in vol. ii. of Taylor's Scientific Memoirs, p. 402. London, 1841.

"With regard to this first law, I have started from the supposition that the communication of the electricity from one particle takes place directly only to the one next to it, so that no immediate transition from that particle to any other situate at a greater distance occurs. The magnitude of the transition between to adjacent particles, under otherwise exactly similar circumstances, I have assumed as being proportional to the difference of the electric forces existing in the two particles; just as in the theory of heat, the transition of caloric between two particles is regarded as proportional to the difference of their temperatures. It will thus be seen that I have deviated from the hitherto usual mode of considering molecular actions introduced by Laplace; and I trust the path I have struck into will recommend itself by its generality, simplicity, and clearness, as well as by the light it throws upon the character of former methods.

With respect to the dispersion of electricity in the atmosphere, I have retained the law deduced from experiments by Coulomb, according to which, the loss of electricity in a body surrounded by air, in a given time, is in proportion to the force of the electricity, and to a coefficient dependent on the nature of the atmosphere. A simple comparison of the circumstances under which Coulomb performed his experiments, with those at present known respecting the propagation of electricity, showed, however, that in galvanic phenomena the influence of the atmosphere may almost always be disregarded. In Coulomb's experiments, for instance, the electricity driven to the surface of the body was engaged in its entire expanse in the process of dispersion in the atmosphere; while in the galvanic circuit the electricity almost constantly passes through the interior of the bodies, and consequently only the smallest portion can enter into mutual action with the air; so that in this case, the dispersion can comparatively be but very inconsiderable. This consequence, deduced from the nature of the circumstances, is confirmed by experiment; in it lies the reason why the second law seldom comes into consideration.

The mode in which electricity makes its appearance at the place of contact of two different bodies, or the electrical tension of these bodies, I have thus expressed: when dissimilar bodies touch one another, they constantly maintain at the point of contact the same difference between their electroscopic forces [potentials].

With the help of these three fundamental positions, the conditions to which the propagation of electricity in bodies of any kind and form is subjected may be stated. The form and treatment of the differential equations thus obtained are so similar to those given for the propagation of heat by Fourier

and Poisson, that even if there existed no other reasons, we might with perfect justice draw the conclusion that there exists an intimate connection between both natural phenomena; and this relation of identity increases, the further we pursue it. These researches belong to the most difficult in mathematics, and on that account can only gradually obtain general admission; it is therefore a fortunate chance, that in a not unimportant part of the propagation of electricity, in consequence of its peculiar nature, those difficulties almost entirely disappear."

From these premises, and guided by results of experiments made by him and by Ritter, Erman, Jäger, Davy and Becquerel he arrived at the following conditions as existing in a voltaic circuit.

1. In a homogeneous conductor, forming part of a voltaic circuit, the difference of the electric tensions at any two points of the conductor is proportional to their distance.

2. In different conductors forming part of a circuit, the difference of tensions at two points separated by an interval equal to the unit of length is in the inverse ratio of the section of the conductor and of its coefficient of conductivity. Hence, in different conductors, equal differences of tension correspond to lengths whose electric resistance is the same.

3. At the point of contact of two different conductors, there is a sudden variation of electric tension.

4. If A equals the sum of the electro-motive forces, L the resistances, λ the resistance reckoned from a point m of the circuit to a point p when the tension is zero, the tension at the point m is given by the formula

$$u = A\frac{\lambda}{L}.$$

Ohm eventually arrives at the formula $S = \frac{A}{L}$, which expresses what is generally known as his law. Which formula, he says, "is generally true, and already reveals the equality of the force of the current at all points of the circuit; in other words it may be thus expressed: The force of the current in a galvanic circuit is directly as the sum of all the tensions, and inversely as the entire reduced length of the circuit, bearing in mind that at present by reduced length is understood the sum of all the quotients obtained by dividing the actual lengths corresponding to the homogeneous parts by the product of the corresponding conductivities and sections."

The words "tension" (*Spannung*) and "electromotive force" used by Ohm are the equivalent of the word *potential*. He was the first to introduce this conception into the theory of

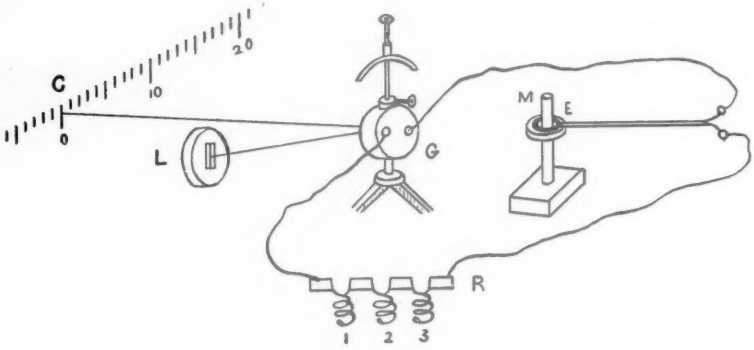
the voltaic circuit and to the above words and to *current* and *resistance* he attached precise meanings and showed the relations existing between those quantities. The clear definitions Ohm gave of these terms marked a transition from vague ideas of "quantity" and "intensity" to the clear conceptions of potential, electromotive force, current and resistance. The word *energy* he also used with clear and accurate meaning as is shown in the following statement: "that the decomposing force of the circuit is in direct proportion to the energy of the current, and moreover, that it depends on a coefficient, to be derived from the nature of the constituent parts and their chemical equivalents." This was published in 1827, six years before Faraday's researches on electrolysis.

Neither Ohm nor his contemporaries were able to test the truth of the four statements given above as embodying Ohm's theory. It was reserved for Kohlrausch in 1849 to show by very ingenious and accurate experiments that Ohm's statements were true in mode and in measure. Kirchhoff * and Quincke † applied with success Ohm's theory to the flow of electricity in thin conducting plates, or bodies of two dimensions, and the same was done by Smaasen ‡ not only in a plane but in bodies of three demensions. The most remarkable confirmation of Ohm's law was made in 1876 § by experiments, suggested by Maxwell and performed by Chrystal in the Cavendish Laboratory, Cambridge, "in which the testing of this law seems to have been carried to the limit of experimental resources."

Though Ohm's law has thus received such ample verification that it ranks with the best established laws of nature, yet, as Maxwell says, "Ohm's law must, at least at present, be considered a purely empirical one. No attempt to deduce it from pure dynamical principles has as yet been successful. . . . The conduction of electricity through a resisting medium is a process in which part of the energy of an electric current, flowing in a definite direction, is spent in imparting to the molecules of the medium that irregular agitation which we call heat. To calculate from any hypothesis as to the molecular constitution of the medium at what rate the energy of a given current would be spent in this way, would require a far more perfect knowledge of the dynamical theory of bodies than we at present possess. It is only by experiments that we can determine the laws of processes of which we do not understand the dynamical theory."

* Pogg. Ann., t. lxiv, 1845, and t. lxvii, 1846.
† Pogg. Ann., t. xcvii, 1856.
‡ Pogg. Ann., t. lxiv, and t. lxxii.
§ Brit. Assoc. Rept., 1876, p. 36.

Surely if an experiment, that is easily made, shows the truth of a law of such theoretical and practical importance as that of Ohm, even if it is one restricted in its range of C, E and R, but shows within its limitations the relations $C=\frac{E}{R}$, then it should be made by all teachers of Physics so that clear physical conceptions of those relations may be given to students. As those who have seen these experiments have deemed them worthy of being more generally known, I now publish an account of them.



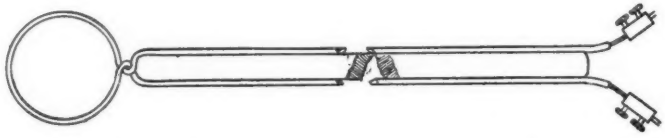
In the diagram the parts of the apparatus are shown, but not at their relative distances apart or in the proper proportions as to size. G is a low-resistance Thomson-galvanometer. At L is the condensing lens of a lime-light lantern, which is covered with a cap having a rectangular opening in it. Across the middle of this slit is a vertical wire. The scale of the galvanometer is at C, distance 165^{cms} from the mirror of the galvanometer. The width of the divisions on this scale are 2·5^{cms}, and the lines are drawn 2·5^{mms} in breadth, or $\frac{1}{1\,5}$ the distance apart of the centers of the lines forming a unit of the scale. The scale is at such distance from the galvanometer-mirror that the image of the vertical slit just fits in the space of a scale unit, while the breadth of the image of the vertical wire is exactly equal to the breadth of a scale line. This arrangement gives the means of observing a deflection of the beam of light to $\frac{1}{10}$ and $\frac{1}{20}$ of a unit with quickness and accuracy.

The image of the slit is so bright and that of the wire so distinct that this method of observing deflections of the galvanometer may be used in broad day light and the deflections may be read throughout the room.

An incandescent electric lamp with a part of its surface (behind the plane of its filament) silvered may replace the lime-light. Thanks to this arrangement, I have been able during many years to make before my class electrical measurements, and to measure the radiation, reflection, refraction, diathermancy and polarization of radiant heat.

At M is a magnet 25^{cms} long and 1½^{cms} in diameter. On this magnet slides a wooden disc. At R is box containing 1, 2 and 3 Ohms of resistance, made of coils of copper wire.

An insulated copper wire wound at its middle in a circle of one coil, or in a spiral of any number of coils is placed over the magnet and rests on the top of the wooden disc. The figure



shows, (one-half size) how this circle of one coil is made. It is bent around a wooden cylinder 3½^{cms} in diameter, and then the free ends of wire are bent one half turn on each other. The free lengths of the wire are then lashed to a light square rod of wood as shown in figure. The wire and rod are then coated with shellac to cement them firmly together. Rings of spirals of 2, 3, 4, 5 and 6 coils are also made in the same manner, but the coils are in a spiral, i. e. in one plane, and are then cemented together with shellac between rings of thin card-board.

The length of wire forming each of these rings of spiral coils with the portion on its handle is one meter long.

The resistance of this length of wire added to the resistance of the lengths between it and G and R, together with the resistance of the galvanometer is (for convenience) made one ohm.

It may be well here to speak of the adjustment of the galvanometer before describing the experiments, for I have noticed in some laboratories and lecture rooms galvanometers which are used not as they should be. I have noticed that the damping-magnet formed a considerable angle with the plane of the coil. This was either because the median plane of the coil was not in the magnetic meridian or because there was considerable torsion in the suspending thread.

In these galvanometers, or, at least, in mine, the median plane of the coil is placed parallel to the faces of the drum of the instrument. The plane of one of these faces is brought in the magnetic meridian of the room, which has been carefully

drawn on the table under the vertical center line of the galvanometer coil, by means of a long magnetic needle mounted like those used on plane-tables. A line at right angles to this meridian is now drawn so that its point of intersection with the meridian line shall be exactly under the suspending thread of the mirror. In the vertical plane of the line, drawn at right angles to the meridian, is placed the vertical wire in the slit of the lantern, L, and also the zero line of the scale C. The scale is parallel to the magnetic meridian. The galvanometer is now placed in the position given above and the "directing magnet" removed to a distance. The image of the vertical wire at L will now be found on the zero of the scale if there is no torsion in the suspending thread. If it does not come to zero then the head of the rod to which the thread is attached is turned till image of wire coincides with zero of scale, and then the instrument is in adjustment, and it will give deflections as the tangents of the strength of current, or, in other words, the current strength will be directly as the readings on the scale. The magnet M is now placed so that it causes no movement of beam from the zero of the scale. The directing magnet, above the coil, is now so adjusted that the time of an oscillation of the magnets of the galvanometers is above 5 seconds.

The coil, E, over the magnet is put in the circuit of G and R. The wires between E and G and R are twisted and tied together so that no induced current from the earth's magnetism may be caused by the motions of this part of the circuit. The image of wire is on zero of scale. Now on rapidly lifting the coil from around the magnet a deflection is produced by the magneto-electric current thus generated. It is sufficient to know that the cause of this current is the quick lifting of the ring with one coil. If we replace this by a ring of two coils we get twice the deflection, and rings of 3, 4, 5, and 6 coils gives 3, 4, 5, and 6 times the deflection given by the ring with one coil. Adopting the conception of the lines of magnetic force, we say that the ring with one coil cuts a certain number of these lines, this cutting of the lines causes the current, and is *the electromotive force.* The ring with two coils makes two cuts of these same lines, or, cuts double the number of lines, the rings of 3, 4, 5 and 6 coils cut 3, 4, 5 and 6 times the number of lines and hence give 3, 4, 5 and 6 times the electromotive force.

In these experiments the resistance of the circuit has remained constant. Now take the ring with 5 or 6 coils and let us have one ohm as resistance of circuit. On lifting ring from magnet we get a certain deflection, which we may make exactly equal to a whole number of the units of the scale by

sliding up or down the disc on the magnet. We now take out plug of resistance box and make resistance of circuit two ohms. The deflection of the galvanometer magnet now becomes one half of that of previous experiment, and successively making the circuit with resistances of 3, 4, 5, 6, and 7 ohms we get, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, and $\frac{1}{7}$ of the deflection we got with one ohm in circuit.

When these experiments are made with the galvanometer in perfect adjustment, and with the precautions indicated below, the deflections arrive one after the other exactly as the law requires. Thus showing with sufficient precision for a lecture experiment that the current is directly as the electromotive force and inversely as the resistance. Indeed generally the closest scrutiny does not detect in the scale reading any departure from the law.

Certain precautions are, however, necessary in these experiments. The resistance outside the galvanometer must be of copper wire, for such is the wire of the galvanometer. Also, the whole of the apparatus must be put together the day before we make the experiments, and the room maintained at as constant a temperature as possible, so that the temperature of all parts of the apparatus is the same. The deflections should not exceed 15 divisions of the scale. Thus, if we start with 15 divisions of deflection for a resistance of one ohm we will get 7·5; 5; 3·75; 3; 2·5; and 2·143 deflections for resistances of circuit of 2, 3, 4, 5, 6 and 7 ohms; and if with a constant resistance we obtain a deflection of 2 divisions of scale with a ring of one coil, we will get deflections of 4, 6, 8, 10, and 12, with rings having 2, 3, 4, 5 and 6 coils.

It is necessary that the coils should be removed from the magnet *very quickly*, otherwise the deflections will not be as the law requires. In other words, the currents produced should be as instantaneous as can be obtained. Instead of rapidly removing the coils by the hand, I have sometimes lashed the coil and their handles to a spring board with a hole in it which went over the magnet. By a trigger this spring-board is released. We thus get the same velocity in lifting the coil in each experiment. We have found, however, that the hand of a good experimenter gives precise results. Sometimes I have sent the coil from the magnet by the blow of a stick delivered on the under side of the handle of the coil at its center of percussion. There is no doubt some departure from the law in these experiments, for it is not possible in such experiments to obtain what is understood by instantaneous currents; and the damping of the magnet by the mirror acting on the air must come into play. Yet I have never seen any

but insignificant and barely discernable departures from deflections required by the law. This follows from the small angles of deflections and low velocity of the motion of the galvanometer magnet in the experiments. It is also to be noticed that with a good magnet of the size stated, and with the galvanometer making one vibration in about 5 seconds, the coil with 5 turns passes over only 2 cms. or less, of end of magnet in order that it shall give a deflection of 15 divisions of scale. It is evident that in these conditions a very short time is occupied in cutting the lines of force. If the maximum deflection used is 15 divisions of the scale, the actual angular deflection of the magnets and mirror amounts to only 6° 29′. Yet 15 divisions are quite a length on the scale, being equal to 37·5 cms. But these experiments may be as readily made with a ballistic galvanometer. Then the magnets and coils have to be of larger dimensions.

Experiments similar to those given have served to graduate galvanometers. We have here the means of sending definite amounts of currents through an ordinary galvanometer and we may thus graduate its angular readings into their relative values in current. The damping of the galvanometer has, however, to be applied to the readings, and then the results may best be put in the form of a curve.

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Art. IV.—*Microscope Magnification;* by W. LeConte Stevens.

When a lens is interposed as magnifier between the eye and an object, it produces a virtual image of this, the accommodation of the eye being so adjusted as to relax the ciliary muscle and thus secure the most comfortable vision. For normal eyes this occurs when the entering rays are parallel, rather than when the accommodation is for the conventional near-point of distinct vision. The position of the virtual image is hence indeterminate; but by common consent it has been generally agreed to consider its distance on the axial line to be 10 inches, or 254 millimeters, from the optical center of the lens.

It can be easily shown that, if the lens and object be fixed, the increase of visual angle produced is a maximum when the eye is closest to the lens. It is never possible to measure accurately the distance from the optical center of the lens to that of the refracting combination composing the observer's eye. In theoretical calculations an allowance should be made for it; practically it is regarded as zero.

By some authors a distinction is made between the terms "magnification" and "amplification," and still further between "relative," "comparative," and "absolute" amplifying power.* Whatever may be the value of these distinctions in theory the writer can find no good reason for discarding the familiar term, magnification, to denote the ratio of the diameters of the retinal images produced with and without the magnifying lens, or system of lenses, respectively. The conditions under which the magnifying system is employed are to some extent arbitrary.

To compute the magnification given by a microscope it is necessary to multiply together the separate magnifications due to the eye-piece and objective employed. Unfortunately the nomenclature of eye-pieces and objectives is still far from satisfactory; and it would perhaps be safe to say that the majority of persons who employ them are unable, under existing limitations, to do more than accept certain labels and use these in calculation. But the labels are misleading. To call an eye-piece "shallow" or "deep," or to name it an A, B, or C eye-piece, affords no definite idea of its power. Such arbitrary and useless designations deserve to be abolished. An eye-piece should be labeled with its equivalent focal length like an objective; and in each case the label should be accurate to within one millimeter. This method of labeling eye-pieces was recommended several years ago by the American Society of Microscopists, but thus far there has been very little compliance on the part of manufacturers. Tables of magnification are given by certain firms for combinations of objectives with eye-pieces as sold by them; but the purchaser has to take these figures on trust. They are professedly applicable only when "standard tube-length" is employed. Such a standard exists only in name and not in fact. In 1887 Professor S. H. Gage, of Cornell University, applied to all of the prominent makers of microscopes in the world for information as to the tube-length for which their objectives were corrected, enclosing to each a diagram upon which should be marked those points on the microscope body which were taken as the limits of tube-length. From eighteen of these firms, including the majority of those addressed, satisfactory answers were obtained. Among the lengths given, the following in millimeters may be taken as examples: 125, 146, 150, 160, 165, 180, 190, 200, 203, 216, 220, 228, 250, 254. The last of these numbers occurs most frequently, corresponding to 10 inches. Examination of the diagrams revealed equal diversity in regard to the points taken as the limits of tube length. In one case it was from the upper surface of the eye lens to the lower extremity of the objective; in another, from

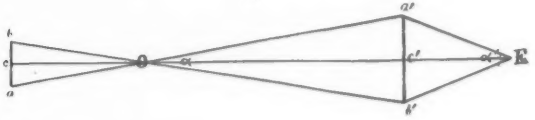
* L. Didelot, "Du Pouvoir amplifiant du microscope," Paris, 1887.

the upper surface of the field lens to that of the topmost lens of the objective.

The present writer had occasion, some time since, to purchase a binocular microscope, with several objectives and eye-pieces, for which a table of magnification was furnished. Examination of this table showed that the magnification was calculated by dividing 100 by the product of what were called the focal lengths of objective and eye-piece, expressed in inches. On inquiry of the dealer this rule was found to be the one he had employed, and it was said to be in common use. Its results were admitted to be only approximate, but it was supposed to be near enough to the truth for most practical purposes.

It has seemed desirable, therefore, to test this rule, and in so doing to search out a few points that may possibly be of interest to those who use the microscope as a physical instrument. Its deduction is very simple. Let the object, ab, be

1.



focalized by the objective, O, at $a'b'$. Oc is taken as the focal length of the objective, and Oc' as the tube-length, 10 inches. If m be the magnifying power of the objective alone, we have,

$$m = \frac{a'b'}{ab} = \frac{10}{f}.$$

The visual angle, α, subtended at O by $a'b'$ is the same as that subtended by ab, if an eye placed at O were capable of sufficient accommodation to secure distinct vision at so short a distance. The image, $a'b'$, is viewed with an eye-piece, which increases the visual angle from α to α', producing a virtual image which is assumed to be 10 inches away. If m' be the magnifying power of the eye-piece whose focal length is f', we have, approximately,

$$m' = \frac{\tan \frac{1}{2}\alpha'}{\tan \frac{1}{2}\alpha} = \frac{10}{f'}.$$

If M be the total magnification, the result therefore is

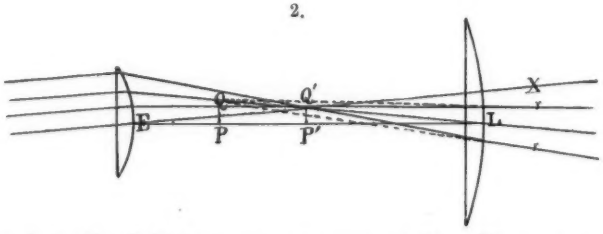
$$M = mm' = \frac{100}{ff'}. \quad . \quad . \quad . \quad (1).$$

In applying this formula, if previous measurements have not been made upon the lenses composing the eye-piece, a

difficulty arises in regard to the value to be assigned f', since eye-pieces ordinarily have no labels more intelligible than A, B, or C, which numerically mean nothing. If a positive eye-piece be employed, the focal length of its two lenses being equal, the equivalent focal length of the combination is obtained by the usual formula, if that of either of the two lenses, and the interval between their optical centers, be measured. In case the eye-piece be negative, a majority of those in use belonging to this class, the focal length of its eye lens is easily found by allowing for its thickness and measuring down to the diaphragm where the real image is formed. But the size of this image has been decreased, and its position has been changed by the interposition of the field lens. At the risk, therefore, of giving what seems very elementary, it may be well to consider briefly the theory of the negative eye-piece.

We may assume the proportions usually said to be adopted in the construction of the negative eye-piece, that the focal length of the field lens is three times that of the eye lens, and the interval between these equal to the difference of their focal lengths. The rays, $r\,r$, fig. 2, converging from the objective toward the point, Q, have their convergence in-

2.



creased by the field lens, so as to cross at Q′. They are made parallel by the eye-lens, and emerge so as to produce a virtual image which to the receiving eye appears in the direction E X. Hence Q′ is in the principal focal plane of the eye lens, and Q in one conjugate focal plane of the objective.

Let $EP' = f'$ = focal length of eye lens.
" $3f' = f''$ = " field lens.
" $LP = p$ = distance of virtual point of radiance.
" $LP' = p'$ = " actual " convergence.

Then, by the fundamental law of lenses,

$$\frac{1}{p'} - \frac{1}{p} = \frac{1}{f''}.$$

Since $EL = 2f'$, and $EP' = f'$, we have $p' = f'$. Hence,

$$\frac{1}{f'} - \frac{1}{p} = \frac{1}{3f'} \quad \therefore p = \frac{3}{2}f'$$

$$\therefore PQ = \frac{3}{2} P'Q'.$$

The focal plane of the objective is hence midway between the eye lens and its focal plane; and the diameter of the image actually viewed with this lens is two-thirds of that which would have been formed if the field lens had been absent. If we assume $\frac{10}{f}$ as the magnifying power of the objective when no field lens is used, the interposition of this lens reduces it to $\frac{2}{3} \cdot \frac{10}{f}$. This reduction of magnification is more than offset by the well known advantages which the field lens confers. Introducing the proper correction in formula (1), this becomes

$$M = \frac{2}{3} \frac{100}{ff'} \quad . \quad . \quad . \quad . \quad . \quad (2).$$

Formula (2) implies a knowledge of the focal length of the objective and of only the eye lens. To find the equivalent focal length of the eye-piece combination, let F stand for this length, f' and f'' for those of eye lens and field lens respectively, and d for the interval between these lenses. Then the usual formula for the combination is

$$\frac{1}{F} = \frac{1}{f'} + \frac{1}{f''} - \frac{d}{f'f''} \quad . \quad . \quad . \quad . \quad (3).$$

In this case $f'' = 3f'$ and $d = 2f'$. Substituting, we have

$$f' = \frac{2}{3} F. \quad . \quad . \quad . \quad . \quad (4).$$

Introducing this value of f' in formula (2), the result is

$$M = \frac{100}{Ff} \quad . \quad . \quad . \quad . \quad (5).$$

The value of f is labeled on the mounting of the objective, and that of F is easily obtained by applying formula (4), f' being found without calculation, as suggested above, if great accuracy is not required.

In formula (5), 100 is the product of two factors. One of them is the assumed distance at which distinct vision with the unaided eye is most easily attained. It may be taken as 250 millimeters, which is very nearly 10 inches. The other is the distance from the focal plane of the objective to what we may provisionally call its optical center. If we make this last distance our definition of tube length, use for it the symbol T, and let D stand for the distance of distinct vision, our formula becomes,

$$M = \frac{DT}{Ff} \quad . \quad . \quad . \quad . \quad (6)$$

It remains now to be seen what modifications need to be imposed upon formula (6), since formula (1), from which it is developed, is confessedly only approximate. Its second member should be equal to the product of the magnifying powers, m and m', of objective and eyepiece respectively, as determined by experiment.

Assuming that the eye-piece has been constructed in accordance with the conditions implied in the formula, F is to be determined from f'', which in turn can be measured with but little error by use of the camera lucida. Let an eyepiece micrometer be placed at the diaphragm and properly illuminated, the microscope body being so tilted that the optical center of the eye lens shall be 250^{mm} above the white paper on the table. With the camera lucida the divisions of the micrometer are projected on the paper, and the magnification, m', is directly determined. To find f'', since the image is virtual, the value of m' is substituted in the formula,

$$m' = \frac{D}{f''} + 1 \quad . \quad . \quad . \quad . \quad (7)$$

This method may be checked by detaching the eye lens and testing it independently by Cross's formula, to be presently given.

The value of f, the focal length of the objective, cannot be determined by ordinary methods because the microscope objective usually consists of two or more systems of lenses, each made up of a crown and a flint; and the error involved in measuring the thickness of each of these separately and also their distance apart is so considerable as to make the final result very uncertain. The best formula to apply is that deduced some years ago by Prof. C. R. Cross.* This formula is of such importance that its deduction and application are best given in this connection.

Let the field lens of the eye-piece be removed, and two micrometer scales be employed, one of which, divided into 10ths of a millimeter, is placed on the stage as an object, while the other, divided into millimeters, is placed at the diaphragm in the focal plane of the eye lens. The image of the stage micrometer is focused upon the eye-piece micrometer, and the comparison of these images gives the magnifying power, m, of the objective at the distance selected. Assuming provisionally an optical center for the objective under the given conditions,

* Journal of the Franklin Institute, vol. lix, p. 401.

Let p = distance of stage micrometer from this optical center.
Let p' = " eye-piece " " "

Then,
$$m = \frac{p'}{p}, \text{ or } p = \frac{p'}{m} \quad . \quad . \quad . \quad (8)$$

It is impossible to measure either p or p' directly, but we can measure the distance between the two micrometer scales, which is equal to their sum. Calling this l, we have,

$$l = p + p', \text{ or } p = l - p' \quad . \quad . \quad . \quad (9)$$

Eliminating p between equations (8) and (9),

$$p' = \frac{ml}{m+1} \quad . \quad . \quad . \quad . \quad (10)$$

From the equation of lenses,

$$\frac{1}{p} + \frac{1}{p'} = \frac{1}{f}, \text{ we have } f(p+p') = pp' \quad . \quad . \quad (11)$$

Substituting in equation (11) from equations (9) and (10), and reducing, the result is

$$f = \frac{ml}{(m+1)^2} \quad . \quad . \quad . \quad . \quad (12)$$

Since this formula is independent of p and p', it may be applied without any knowledge of the optical center of either a single lens or a system of lenses.

The eye-pieces of the microscope to which reference has been already made are devoid of labels, although the instrument is a fine one, and the maker was one of the best known in America, a careful and intelligent German, now dead. They have been subjected to measurement, with the result given in Table I. The two eye-pieces labeled in the table A_1 and A_2 were evidently intended to be, in ordinary nomenclature, 2-inch eye-pieces; those labeled B_1 and B_2, 1½-inch eye-pieces, and the one labeled C, a ¾-inch eye-piece. All measurements of length were made in millimeters.

TABLE I.

1.	2. f'	3. f''	4. d	5. F	6. $\frac{3}{2}f'$	7. F′	8. $e\,\%$	9. m'
A_1	35·5	58·8	54·0	51·8	53·2	2·07	−3·4	5·82
A_2	34·9	58·1	54·0	52·0	52·3	2·08	−3·9	5·82
B_1	21·3	40·0	38·0	36·6	31·9	1·46	+2·7	7·83
B_2	21·1	40·9	38·0	36·0	31·6	1·44	+4·2	7·94
C	13·6	28·7	23·0	20·2	20·4	·81	−7·4	13·38

On comparison of columns 2, 3, and 4, it is seen that in no case is $f'' = 3f'$, or $d = 2f'$, as generally assumed in relation to the negative eye-piece. To multiply the focal length of the

eye-lens by $\frac{8}{3}$ does not therefore give the equivalent focal length of the combination. The approximation, as shown in colums 5 and 6 is moderately good in eye-pieces A_2 and C, but by no means so in B_1 and B_2. In column 5 the value of F was computed by formula (3), and the results translated into inches for column 7. Column 8 shows the percentage of error in the nominal equivalent focal lengths of the eye-pieces, and column 9 shows their actual magnifying power. Each of the data of columns 2 and 3 is the mean of five independent measurements; but the results in column 9 are affected with a probable error greater than what should be expected if F could have been obtained directly from f'' alone.

The maker of an eye-piece ought certainly to know how to test his work after it is finished. He has the right to use any formula in construction that experience has shown to be valuable. But in every case the value of F ought to be determined accurately by him, and labeled on the mounting of the eye-piece, not in whole inches or aliquot parts of an inch, but in decimal parts of an inch, or, still better, in millimeters. The scientific world is familiar enough with the metric system to warrant the abolition of other systems, at least in the construction of all new instruments.

TABLE II.

1.	2.	3.	4.	5.	6.
	l	*m*	*f. mm.*	*f. inches.*	*e%*
W. 3	315	3·93	51·0	2·01	+50
B. 2	303	6·25	36·1	1·42	+41
R. $1\frac{1}{2}$	300	7·10	32·4	1·28	+17
B. 1	293	9·33	25·6	1·01	−1
B. $\frac{2}{3}$	284	13·50	18·2	·716	+5
W. $\frac{2}{4}$	296	14·00	18·4	·724	+4
B. $\frac{1}{3}$	288	18·80	13·5	·531	−6
C. $\frac{1}{4}$	290	55·00	5·1	·202	+24
B. $\frac{1}{5}$	283	58·00	4·7	·185	+7
W. $\frac{1}{1\frac{1}{2}}$	277	115·0	2·36	·093	−10
B. $\frac{1}{16}$	287	170·0	1·68	·066	−5

In applying formula (12) to the determination of the focal lengths of objectives it is found that the labeling of these is in many cases very erroneous. In the paper to which reference has already been made Professor Cross gave his measurement of more than thirty objectives from various sources. In one case, an objective, marked $\frac{4}{10}$ inch, should have been marked $\frac{1}{4}$ inch. The measurements made by the present writer and recorded in Table II above, may give some idea of current errors

in this respect. In column 1 the capital letter arbitrarily stands for the name of a maker, and the adjacent figures for the focal length of the objective as labeled, in inches or fractions of an inch, on the mounting. Column 2 gives the distance in millimeters between the stage and eye-piece micrometers, determined by the length of the microscope body; and column 3, the corresponding magnification attained. Column 4 gives the computed focal length in millimeters, which in column 5 is reduced to inches for the sake of comparison; and column 6 gives roughly the percentage of error of the label.

On examination of Table II it is seen that the errors of the labels are more frequently positive than negative, or that objectives are more frequently labeled too low in power than too high; and that the errors are unpardonably great in the objectives of lowest power. It seems scarcely conceivable that an error of 40 or 50 per cent could be made and deliberately stamped on the mounting of an objective whose real focal length is so easily found by experiment. It should be observed that any error due to thickness of cover glass is negligible when the focal length exceeds 20^{mm}. The stage micrometer used in these experiments was uncovered; and since the higher powers are usually adjusted to give their best definition when a definite thickness of cover glass is employed, this fact may partly account for the negative errors found in the two highest powers examined, although the adjustment of collar in these measurements was for use without a cover glass.

Having obtained the magnifying powers of objective and eye-piece, their product is the total magnifying power of the combination. If the equivalent focal length of the eye-piece is definitely known, its magnifying power, m', is obtained by applying formula (7). If the tube length, T, and focal length, f, of the objective are known, its magnifying power, m, may be accurately obtained. For, referring to fig. 1,

$$m = \frac{a'b'}{ab} = \frac{T}{Oc}. \quad \text{But } \frac{1}{Oc} + \frac{1}{T} = \frac{1}{f}. \quad \therefore Oc = \frac{Tf}{T-f}. \quad \text{Hence,}$$

$$m = \frac{T}{f} - 1. \qquad . \quad . \quad . \quad . \quad (13)$$

In formula (13), if f be very small in comparison with T, the term -1 may for all practical purposes be neglected. But to do this involves serious error when objectives of low power are employed.

Table III shows the result of using eye-piece B_1 of Table I successively in combination with five of the objectives of Table II, the values of m' and m being taken from these two tables. Column 2 gives the values thus calculated, while column 3 gives the corresponding results independently obtained

with the camera lucida. The next two columns result from applying the formula $M = \frac{100}{Ff}$ and reducing to millimeters; in column 4 the values of F and f have been taken from Tables I and II, and in column 5 they are the nominal focal lengths, as indicated by the manufacturers.

TABLE III.

1.	2.	3.	4.	5.
Combination.	$M = mm'$.	Camera.	$M = \frac{100}{Ff}$	$M = \frac{100}{Ff}$
$B_1 \times W.3$	30·8	30·4	34·14	22·22
$B_1 \times R.1\frac{1}{2}$ ...	55.3	55·0	53·68	44·44
$B_1 \times W.\frac{4}{10}$	109·6	107·0	94·60	88·88
$B_1 \times C.\frac{1}{4}$	430.6	433·0	339·0	266·7
$B_1 \times W.\frac{1}{18}$	900.0	900·0	736·0	800·0

Table III shows, as might be expected, that the uncertainty of results increases with the power of the objective. Theoretically, columns 2 and 3 ought to be identical. Practically they are nearly so for low powers, but the difficulty of taking exact measurement with high powers is very great. The inaccuracies revealed in column 4 are due partly to the fact that the formula is only approximate, but also because the tube length is not 250 millimeters, and cannot possibly have this value with the instrument employed. In column 5 erroneous values of F and f, taken from the labeling, so greatly increase the errors of column 4 as to make the measurements worthless. Yet these are the results of calculation as commonly applied to the data furnished by the manufacturers

In using the camera lucida the difficulty increases when the higher powers are employed, just as much as in applying Cross's formula. Under any circumstances, therefore, a wide margin of uncertainty exists in estimating the magnification attained with objectives of high power. Although the figures given are in each case the mean of many measurements, the remarkable agreement in the two results attained with the $\frac{1}{12}$th is doubtless to some extent accidental. With medium and lower powers it is shown by comparison of columns 2 and 3 that results about equal in value to those with the camera lucida are had by taking the product of the separate magnifications due to objective and eye-piece. And formulas (6), (7) and (13) show that this product may be expressed as

$$M = \frac{(D+F)(T-f)}{Ff} \quad . \quad . \quad . \quad (14).$$

This formula is fully worthy of reliance if accurate values of the equivalent focal length of eye-piece and objective, respectively, are stamped on their mountings, and if the tube-length also is stamped on the microscope body.

But the difficulty of securing definiteness and uniformity in tube length is probably greater than that of securing proper labels on the mountings of the lenses. It is necessary to fix upon two points of the microscope body as the upper and lower limits of the tube-length, and additionally for some agreement to be reached among makers as to the tube-length selected. What this shall be is a matter partly of precedent, partly of convenience. The nominal standard is 10 inches in England and America, but there is no pretense of adhering to it. In Germany and the continent of Europe generally, about 180 millimeters is perhaps most common. The latter is for some reasons more convenient, and seems to be gaining in popularity.

From what has preceded it is obvious that the upper limit of the tube-length should be the focal plane in which an image would be formed by the objective if no field lens were interposed. If the eye-piece is made to fulfil the generally assumed condition that the focal length of the field lens shall be three times that of the eye lens, and the interval between them shall be twice the focal length of the eye lens, the focal plane in question would be just midway between the diaphragm of a negative eye-piece and the optical center of the eye lens, which is at the middle of its convex surface. The eye-piece should be so constructed that when it is slipped into position this focal plane shall be exactly at the top of the microscope body, which then serves always as the upper limit of tube-length. The desirability of making all eye-pieces thus "parfocal" has been already suggested by several writers. There is no practical mechanical difficulty in attaining this end. In case the negative eye-piece should not fulfil the generally assumed conditions, the distance of the parfocal plane above the diaphragm is easily found. Referring to Fig. 2, and using the same notation, this distance is P′P, or $p-p'$, which, from the formula $\frac{1}{p'}-\frac{1}{p}=\frac{1}{f''}$, is equal to $\frac{p'^2}{f''-p'}$. The required distance of parfocal plane above diaphragm is thus given in terms of the focal length (f'') of the field lens and the distance (p') of the diaphragm from the optical center of this lens.

It should in justice be mentioned in this connection that at least one celebrated European firm, that of Carl Zeiss, in Jena, has for several years past been making all of its eye-pieces parfocal. This is only one of the many good things for which the scientific world is indebted to Professor E. Abbe, a phys-

icist whose work in microscopical optics has been so thorough that scarcely anything in this domain can be undertaken by his cotemporaries which he has not already mastered. It is to be regretted that the makers of microscopes generally should be so slow in following a good example.

The determination of the lower limit of the tube length is slightly complicated by the fact that a microscope objective consisting of two or more systems of lenses, has no fixed point through which all axial rays will cross when the position of the point of radiance is varied. Its equivalent focal length varies within narrow limits according to the distance of the focal plane in which the image is formed. According to the writer's experiments it increases slightly as this distance is increased. The objective labeled R. $1\frac{1}{2}$ in Table II was examined on an optical bench, the distance, l, between the points of radiance and convergence being varied from 160 mm. to 700 mm., and f calculated for 20 successive values of l. The mean of the first 10 values was 32·14 mm.; that of the second 10 was 32·38 mm., the extremes being 32·0 mm. and 32·5 mm. This objective consisted of two systems of lenses. A three-system objective of nominal $\frac{1}{4}$ inch focal length, and an objective of one system, were likewise examined, with the result shown in Table IV:

TABLE IV.

Label of Objective	W. 3	R. $1\frac{1}{2}$	C $\frac{1}{4}$
Number of systems	1	2	3
Limits of l, in mm.	202–800	160–700	130–520
Number of measurements	12	20	14
f from first half, in mm.	50·05	32·14	5·60
f from second half, in mm.	50·00	32·38	5·70

From this table it is seen that the variation does not exceed a tenth of a millimeter in the highest of these powers, a quantity that is negligible in comparison with the whole tube-length. Assume then that the distance from the top of the microscope body to the extremity where the objective is screwed in is a little shorter than the desired tube-length; for example, 160 mm., if 180 mm. is selected for tube-length. Then in the formula, $\frac{1}{p}+\frac{1}{p'}=\frac{1}{f}$, we have $p'=180$, and f is known, hence p is calculated. The "working distance" between a slide and the exposed lens can be measured; and on subtracting it from p we have the distance, within the objective, of the point which for the given tube-length behaves like an optical center. This point, by the given formula, is known to be 20 mm. from the extremity of the microscope body, and hence the desired allowance can always be made in the mounting to put this point in its proper place. The optical tube-

length for which an objective is corrected should always be stamped on its mounting along with the record of exact focal length and numerical aperture.

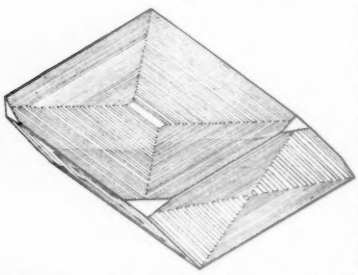
If there be accurate labeling of optical tube-length, and of the equivalent focal length of eye piece and objective, the camera lucida ceases to be a necessity to the user of the microscope. Under present conditions, however, and until better methods are adopted by the majority of manufacturers, it is the only ready means of approximating toward the correct measurement of microscope magnification.

Brooklyn, N. Y., April 2, 1890.

Art. V.—*Notes on the Minerals occurring near Port Henry, N. Y.;* by J. F. Kemp.

During the summer of 1889 the following notes on minerals occurring near Port Henry, N. Y., were made, largely with the aid of Mr. W. H. Benedict, then in charge of the local high school. At the abandoned Pease quarry, a short distance northwest of the town, a face of white crystalline limestone has been laid bare, and in this occur streaks consisting chiefly of hornblende, plagioclase, muscovite and quartz, but containing as well a great abundance of yellowish brown titanite crystals. These latter average perhaps an inch, along *c*, by one-half inch along *b*, and are bounded by large 2P and 0P and less prominent $\infty P\bar{\infty}$ and ∞P—making the common semeline type. Individuals appear to have been wrenched or broken, possibly by mountain-making action. Fine brown tourmalines occur with them in the same associations and are also wrenched and bent. In one instance a crystal one and one-half inches long, is bent around through at least 70°, yet without notable fracturing. West of the Pease quarry is a quarry where flux was being obtained for the local furnaces. The rock is a beautifully clear crystalline limestone with excellent, small, hexagonal tables of graphite disseminated through it. Occasionally lemon yellow calcite is found, but of especial interest are the fine crystals of clear calcite of the general outline of the unit R with a low striated four-faced pyramid imposed on each R face, and often truncated by R

1.



itself. (See Naumann-Zirkel, Mineralogie, fig. 13, under calcite). This is caused by an oscillation between R and two or more scalenohedra, whose long polar edges, and combination edges are on the diagonals of the R face. Although in general the faces are not well adapted to measurement, enough good results were obtained to indicate 2/7 R 9/5 as one of the scalenohedra present above R, and various results for the angle Y led to the suspicion of two others. Below the R face there are also two or more scalenohedra indicated, but the only one of which measurements were obtained proved to be near 13/11 R 9/7.

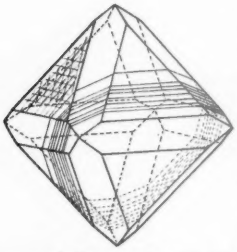
	Y measured.	Y calculated.	X measured.	X calculated.
3/7 R 9/5	166·21	166·10	129·18	130·10
	166·01		129·25	
	165·50		129·27	
			130·12	
13/11 R 9/7	170 43	170·30	Z measured.	Z calculated.
	170·25		96·19½	96·30
	170·26		96·44	

R4 is also present upon all the crystals. The forms determined by Hessenberg on the combination above cited from Naumann were R2 and 2/5 R2. The crystals are excellent illustrations of oscillatory forms. Still west of this quarry is the Treadway quarry in ophicalcite. Through this rock run at times narrow streaks with pyrrhotite, quite large leaves of phlogopite, brown tourmaline and well-crystallized light-brown tremolite (∞P, $\infty P\bar{\infty}$, $\infty P\infty$ and $-P$). A visit to the now abandoned feldspar quarry six miles northwest of Port Henry from which came the peculiar tourmaline crystals described by Professor E. H. Williams (this Jour. III, xi, 273), revealed the fact that it is probably a great feldspathic mass, either in gneiss or granite (probably akin to the pegmatitic segregations common in many granitic masses), and cut by three narrow trap dikes, now much altered but doubtless originally diabase. The tourmalines favor certain lines, and along these they occur in isolated single crystals and as matted aggregates. Great masses of biotite, as large as a barrel occur also in streaks, yielding good cleavage masses under the sledge, and fine specimens of rose quartz are less abundant. The quarry is called Roe's sparbed.

At Mineville, one of the newer openings (the so-called Lovers' Pit) on Barton Hill is affording crystals and cleavage masses of magnetite of unusual size and excellence. The crystals are combinations of O and ∞O, and vary up to an inch and more in diameter. They are buried in granular magnetite of great purity. The faces are marked by striæ parallel with the O edges and at times running quite around the crystal. It

can hardly be said that they favor any one face, for they often divide the O faces into trangles. Other striations occur less abundantly which may be referred to the intersection of planes of ∞O with O, seeming to indicate a minor parting. Striations parallel with the edges of O, have been previously noted by Cathrein (Zwillingsbildung am Magnetit, Zeitschr. f. Kryst. xii, 47, 1887), and again by Mügge (Neues Jahrb., 1889, i, 244), by whom they were regarded as polysynthetic twinning on the spinel law, and due to gliding planes. Such twinnings and striations on spinels proper, have been long known (see Strüver, Zeit. f. Kryst., ii, 480) and are noted in most of the mineralogies. On Cathrein's crystals the striations seem especially to favor one face, and this adds weight to the above explanations. The striations on the Lake Champlain crystals are not especially parallel to any one face, but cross each other frequently, and the other striations parallel to ∞O, add some complexity. The beds which contain them have been subjected to great dynamic movements and these partings are very probably due to pressure—which has also developed the fine pseudocleavage planes in the massive mineral. If it were allowable to conceive of a chief parting along O, and a rarer one along ∞O, occasioned by such pressure, without any accompanying twinning, I should think it more likely to be the true cause of the phenomena. The massive mineral shows these octahedral parting planes quite as large as the hand.

2.



Geol. Laboratory, Cornell University.

ART. VI.—*Occurrence of Goniolina in the Comanche Series of the Texas Cretaceous;* by ROBERT T. HILL.

FOR several years I have been puzzled by a peculiar organism which occurs abundantly in the basal and medial beds of the Comanche series of the Texas Cretaceous. This organism is preserved in chalky beds of whose lithologic character it partakes, and is about the size and shape of ordinary playing marbles used by boys except that it is slightly elongated, and flattened at one end where there is a circular depression resembling the point of attachment between a fruit and its stem. The surface is minutely pitted or reticulated.

Possessing no library facilities at Austin, I recently sent suites of these fossils to various paleontological friends in the

scientific centers of the east, all of whom pronounced them an undertermined species of the genus Goniolina, of D'Orbigny, but as to where the genus belonged in the animal or vegetable kingdom, no one felt positive as attested by the following letter from a gentleman who is considered one of our ablest conchologists.

"The fossil you send belongs to a group which has puzzled paleontologists for many years, and has been referred to almost every obscure group of paleozoölogy and botany. They were named *Goniolina* by Orbigny, who put them among the Foraminifera. Dr. White has shown me a French publication by Dumortier in which a Jurassic species is referred to the *Crinoidea;* Zittel says that Saporta has decided that they are the fruit of *Pandanus* or "screw pine." My own opinion is that they are *fruit* of some kind, and Saporta's reference is the the most likely to be correct. Yours should be Lower Cretaceous."

The above letter indicates a remarkable diversity of opinion. But I think a brief examination of its place and mode of occurrence will remove this species at least from any suspicion of being the fruit of land vegetation. It begins in the Colorado river section at the first (lowest) fossiliferous horizon in the basal Fredericksburg bed above the Trinity sands, and ranges upward through 450 feet of sediments into the base of the Comanche Peak chalk. There beds in which it occurs are pulverulent chalks and all comparatively deep sea deposits. In the lowest there are slight traces of finest comminuted sand; in the upper, there are no sands or clays, but the strata are all chalky and magnesian. In none of the beds are there lignites, or other traces of land debris, which would probably be the fact if the Goniolina were vegetable, while the molluscan associates of the form are all off-shore species, such as *Monopleura*, *Toxastes*, *Tylostoma* and many other forms. At the horizon of its chief occurrence it is associated with a chalk composed almost entirely of a large foraminifer which Roemer named *Orbitolina Texana*,* and which Meek† later referred to the genus *Tinoporus*.

Zittel‡ refers the genus to the family Cornuspiridæ of the Foraminiferæ and says that it is a Jurassic genus.

Its occurrence in the medial third of the Comanche series—the first noted in America—is of interest, and I shall be glad to furnish specimens to any who desire them.

Austin, Texas, March 5, 1890.

* Kreidebildungen von Texas, F. Roemer.
† Check List of Invertebrate Fossils of North America, p. 1.
‡ Handbuch der Paleontologie, pp. 75, 110, 728.

ART. VII.—*A Method for the Reduction of Arsenic Acid in Analysis;* by F. A. GOOCH and P. E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale College—III.]

HOLTHOFF'S development of Mohr's suggestion relative to the reduction of arsenic acid to the lower condition of oxidation by the action of sulphurous acid,* with the demonstration that arsenic acid can be evaporated even to dryness in presence of hydrochloric acid without danger of significant volatilization, has placed the analysis of ordinary compounds of arsenic, both natural and artificial, within the scope of Mohr's classical and exact method of determination by titration with iodine. As Holthoff left the method, it is satisfactory so far as regards accuracy, and as modified by McCay,† who substitutes for the four hours' digestion heating for one hour in a pressure-bottle, is eminently successful. In the account of the experiments about to be described we detail our experience in an attempt to shorten still further the process of reduction of arsenic acid by making use of hydriodic acid as the active agent instead of sulphurous acid.

In a recent paper‡ we have described a method for the determination of iodine in haloid salts based upon the action of arsenic acid, in the presence of sulphuric acid, according to the equation,

$$H_3AsO_4 + 2H\text{-}I = H_3AsO_3 + H_2O + I\text{-}I,$$

the iodine being completely volatilized, but leaving behind in the arsenious acid produced by the action the record of the amount of hydriodic acid originally present. This reaction we propose to utilize conversely, and to employ potassium iodide in excess, in presence of sulphuric acid, to bring about the reduction of the arsenic acid to arsenious acid which may be determined, after neutralization, by the iodine method. The conditions of the methods are different in that, in the former the hydriodic acid is entirely broken up by the action of the arsenic acid, and the iodine volatilizes easily; while in the latter some hydriodic acid must remain in solution until a very low degree of concentration is reached, and remaining must exhibit its characteristic proneness to retain free iodine.

We find in practice that when a solution made up to contain sulphuric acid, an arseniate and potassium iodide to an amount somewhat in excess of that theoretically demanded to effect the conversion of the arsenic acid to arsenious acid,

* Zeit. f. Anal. Chem., vol. xxiii, p. 378.
† Am. Chem. Jour., vol. vii, p. 373.
‡ This Journal, vol. xxxix, p. 188.

is boiled, iodine is evolved and the color of the liquid passes from the dark red when the iodine is abundant through the various gradations of tint to a canary yellow, and then, as the sulphuric acid reaches a degree of concentration sufficient to determine by its own specific action the liberation of iodine, the color again darkens, and if the process of concentration is continued, and much arsenic is present, crystals of arsenious iodide separate and form more abundantly on cooling. If evaporation is pushed still farther the arsenious iodide begins to volatilize and at the point where the sulphuric acid fumes the liquid loses all color and the arsenic has vanished more or less completely. In one experiment conducted in this manner it was found, by the method to be described later, that of 0·3861 grm. of arsenic pentoxide originally present with 1 grm. of potassium iodide and 10 cm³ of sulphuric acid [1 : 1] the equivalent of 0·1524 grm. remained. In another similar experiment in which, however, only a few milligrams of arsenic oxide were involved not a trace of arsenic remained at the end.

It is obvious that two points in this course of action demand examination at the outset. First, means must be found for removing the remnant of free iodine which is withheld by the hydriodic acid; or of rendering it harmless in the titration process to follow; and, secondly, the degree to which the solution may be concentrated without loss of arsenic must be fixed. In our work upon the converse of this process, we noted particularly the marked influence of the amount of sulphuric acid present upon the degree of concentration necessary to expel the iodine. We turned attention, therefore, at once to this point in the present case and investigated the effect of varying the proportion of sulphuric acid in solutions containing definite amounts of potassium iodide and potassium arseniate. The volume of the solution was made up to about 100 cm³ and concentrated by boiling until the color was faintest. Then, to determine provisionally, and for preliminary purposes, the point at which volatilization of arsenic was likely to occur, the concentration was continued until the arsenious iodide began to separate. The results are tabulated as follows:

KI	As_2O_5	H_2SO_4 [1 : 1]	Volume when color was lightest.	Volume when AsI_3 appeared.
1 grm.	0·1900 grm.	20 cm³	80 cm³	33 cm³
1 "	0·1900 "	15 "	65 "	25 "
1 "	0·1900 "	10 "	40 "	19 "
1 "	0·1900 "	5 "	30 "	11 "

The amount of sulphuric acid which, considering rapidity in concentrating to the proper point, ease in neutralizing the

acid previous to titration, and general convenience in manipulation, seemed to be best was 10 cm^3 of the mixture made by diluting the acid with an equal volume of water. This we fixed upon for use in future experiments and set the limit of concentration at 40 cm^3.

It is manifest from the phenomena described that when much hydriodic acid remains in the solution the last portions of free iodine cannot be completely removed by heat without volatilization of the arsenic. We experimented, therefore, upon the effect of very dilute sulphurous upon the remnant of iodine in liquids constituted as described and concentrated to 40 cm^3, the point of minimum color, the solution of sulphurous acid which we employed corresponding approximately to centinormal iodine. We found that upon adding the sulphurous acid drop by drop to the hot concentrated solution the point at which the color vanished could be determined without difficulty, but that if the solution was permitted to stand a single minute the color of iodine returned, doubtless developed by the action of air upon the hot hydriodic acid. We adopted, therefore, the plan of at once diluting the solution with cold water as soon as the sulphurous acid had done its work and immediately neutralizing with potassium carbonate. When this mode of proceeding was followed we were unable to find evidence of reversion of arsenious acid to arsenic acid, magnesia mixture producing in the solution no precipitate of the ammonium magnesium arseniate.

Following out the same general lines, therefore, we proceeded to the quantitative examination of the process. Portions of a standard solution of the dihydrogen potassium arseniate were measured from a burette into counterpoised Erlenmeyer flasks of 250 cm^3 capacity, and the increase in weight was taken as the measure of the actual amount of the solution employed. Potassium iodide in solution, and 10 cm^3 of sulphuric acid [1 : 1] were added, and the liquid was diluted with water to a volume of about 100 cm^3. A trap made, as described in our paper upon the reverse of this process, by cutting down a two-bulbed drying tube, was hung in the neck of the flask to prevent mechanical loss, and the liquid was rapidly concentrated by boiling until the volume of 40 cm^3, the point at which the color of iodine had faded to a pale yellow, was reached. At this point the flask was removed from the flame, its sides and the trap were quickly washed down, the weak sulphurous acid was added drop by drop from a burette until the color of the free iodine had just vanished, the liquid was immediately diluted with cold water, the free acid was nearly neutralized with potassium carbonate and the point of neutralization was

reached and passed a little by the addition of the acid potassium carbonate. After cooling completely a definite amount of starch solution was added and the titration of the arsenious acid was proceeded with as usual, due correction being made for the amount of iodine necessary to produce the end color into the volume of liquid and starch solution employed.

The value of the standard solution of the arseniate was fixed by two series of determinations. One series was made according to Levol's method of precipitating the ammonium magnesium arseniate and weighing as the pyroarseniate, modified, however, in that the precipitate was collected on asbestus in a perforated crucible and ignited after moistening with ammonium nitrate. In the second series McCay's modification* of Reich's method was followed, excepting that the silver arseniate was collected, dried and weighed on asbestus in a perforated crucible. The mean of several closely agreeing determinations gave for the contents of 50 grms. of the solution in arsenic pentoxide as 0·3824 grm. by Levol's method and 0·3830 grm. by McCay's modification of Reich's process. We took the mean of these figures 0·3827 grm. as the standard of the solution.

The details of the experiments with this solution are recorded in the following table.

KI taken.	H_2SO_4 [1 : 1] taken.	As_2O_5 taken.	As_2O_5 found.	Error.	
1·5 grm.	10 cm³	0·3861 grm.	0·3862 grm.	0·0001 grm.	+
1·5 "	10 "	0·3862 "	0·3856 "	0·0006 "	−
1·5 "	10 "	0·3861 "	0·3862 "	0·0001 "	+
1·5 "	10 "	0·3860 "	0·3862 "	0·0002 "	+
1·5 "	10 "	0·3863 "	0·3862 "	0·0001 "	−
1·5 "	10 "	0·3862 "	0·3862 "	0·0000 "	
1 "	10 "	0·1927 "	0·1922 "	0·0005 "	−
1 "	10 "	0·1928 "	0·1922 "	0·0006 "	−
1 "	10 "	0·1930 "	0·1925 "	0·0005 "	−
1 "	10 "	0·1930 "	0·1927 "	0·0003 "	−
1 "	10 "	0·1936 "	0·1929 "	0·0007 "	−
1 "	10 "	0·1929 "	0·1928 "	0·0001 "	−

Experiments in which smaller quantities of arsenic were handled were made similarly, excepting that the standard solution, from which portions for the tests were measured, was made by diluting the former standard ten times, and centinormal iodine was used in the titration.

When the amount of hydriodic acid in solution is small, correspondingly small amounts of iodine are retained after

* Am. Chem. Jour., vol. viii, p. 77.

KI taken.	H_2SO_4 [1 : 1] taken.	As_2O_5 taken.	As_2O_5 found.	Error.	
1 grm.	10 cm³	0·0383 grm.	0·0380 grm.	0·0003 grm.	−
1 "	10 "	0·0383 "	0·0385 "	0·0002 "	+
0·5 "	10 "	0·0383 "	0·0384 "	0·0001 "	+
0·4 "	10 "	0·0383 "	0·0385 "	0·0002 "	+
0·3 "	10 "	0·0383 "	0·0386 "	0·0003 "	+
0·2 "	10 "	0·0383 "	0·0384 "	0·0001 "	+
0·2 "	10 "	0·0076 "	0·0074 "	0·0002 "	−
0·2 "	10 "	0·0076 "	0·0074 "	0·0002 "	−
0·2 "	10 "	0·0038 "	0·0034 "	0·0004 "	−
0·2 "	10 "	0·0038 "	0·0034 "	0·0004 "	−

concentration. In the following experiments colorless solutions were obtained and, for the sake of comparison with the previous results, these solutions were neutralized and titrated without treatment with sulphurous acid, there being no apparent need for adding it in these cases.

KI taken.	H_2SO_4 [1 : 1] taken.	As_2O_5 taken.	As_2O_5 found.	Error.	
0·2 grm.	10 cm³	0·0038 grm.	0·0035 grm.	0·0003 grm.	−
0·2 "	10 "	0·0038 "	0·0035 "	0·0003 "	−

It appears, therefore, that the average error of the whole number of determinations (twenty-four) made by this process amounts to rather less than 0·0002 grm.−, falling between extremes of 0·0003 grm. + and 0·0007 grm.−. The entire amount of arsenic pentoxide handled in the twenty-four determinations was 3·7352 grms., and of this 3·7309 grm. were indicated in the titration as reduced to the arsenious condition. The loss 0·0047 grm.—the entire error of the process—amounts to 0·13 per cent. of the amount taken.

Certain experiments were made to see whether the period of evaporation might not be dispensed with by so modifying the process that the entire amount of iodine set free in the action of the sulphuric acid, the arseniate, and the iodide might be reconverted at once by sulphurous acid to the condition of hydriodic acid. The conversion was apparently successful, but the results of the modification were several per cent below the truth, indicating that the digestion during evaporation, or the removal of the free iodine, or the combined effect of the two, is essential to the completion of the reduction of the arsenic.

The process as we recommend it may be summarized briefly as follows:—To the arseniate in solution are to be added potassium iodide in excess of the amount needed according to the equation to complete the reduction, and 10 cm³ of half and half sulphuric acid. The liquid is to be diluted to about 100 cm³ and boiled rapidly (with the precautions of trapping as

described) until the volume is decreased to 40 cm³. The color of free iodine is to be bleached by cautious additions of sulphurous acid (corresponding roughly to centinormal iodine) and instantly diluted with water and neutralized with potassium carbonate, the neutral carbonate at the first and afterward the acid carbonate. The whole is to be cooled and titrated as usual with iodine, using starch as an indicator. Its advantage is in the rapidity with which it may be executed, the whole operation being easily completed in a half-hour.

ART. VIII.—*On the Development of the Shell in the genus Tornoceras* Hyatt; by CHARLES E. BEECHER, Ph.D. (With Plate I).

THE leading embryonal characters of the genus *Tornoceras* have been drawn mainly from results obtained in the study of *Tornoceras retrorsum*, von Buch, and allied species from the Devonian of Germany.* Probably the best study of any one of the species is that given by W. Branco of *T. retrorsum*, var. *typum*, Sandberger.† The adult features have been determined from the type *T.* (*Gon.*) *uniangulare* Conrad, and other closely related forms. Hitherto our knowledge of this species has not been sufficient to give a reasonably full diagnosis of the genus in its developmental relations, and the results of the following study aim to supply the deficiency. The importance of this is evident, as the characters of the type are of prime consequence, and because *T. retrorsum* offers some differences in its development, and apparently belongs to one of the more advanced phases in the evolution of the generic stock. Instead of presenting a gradual growth from its simple nautiliform protoconch through several slightly diverging stages, it exhibits, to a degree, the principle of accelerated development, as will be shown hereafter; while *T. uniangulare* has a more uniform and complete growth, and is probably one of the initial and most primitive species of the genus.

Besides the sutural and tubular development, the material studied illustrates the inception and growth of the surface ornaments, and as these features are rarely found, the principles involved are of more than generic application.

* Proceedings Boston Society Natural History, vol. xxii, Hyatt: Genera of Fossil Cephalopods, p. 320, 1883.

† Palæontographica, t. 27. Beiträge zur Entwickelungsgeschichte der fossilen Cephalopoden, 1880.

The specific limits of *T. uniangulare* have not been clearly defined, and many of the forms referred to *Parodiceras* (*Gon.*) *discoideum* Hall, are evidently of the former species. A comparison of the type specimens of both with others which have been grouped with them, as figured in the Thirteenth Report, New York State Cabinet, and in vol. v, pt. ii, of the Palæontology of New York, shows that the first species is really the common one, and so far as known, the second is represented only by the original types.*

The adult differences are mainly noticeable in the depth of the air chambers, and in the sutural curves. They can readily be determined by strictly limiting the characters to those first ascribed to each species. *Parodiceras discoideum* is also apparently without the narrow cone at the bottom of the annular lobe, and the ventral saddle is much less depressed.

The material for this paper is a portion of a collection presented to the museum of Yale University, by Thomas G. Lee, M.D. The particular lot containing the *Tornoceras* consisted of several hundred nodular concretions of pyrite of a radiated structure, obtained from the Devonian (Hamilton) shales of Wende Station, Erie County, New York. Most of them preserved an organic nucleus, and about twenty-five species have been identified as belonging to the Trilobita, Cephalopoda, Pteropoda, Pelecypoda, Brachiopoda and Crinoidea.

The test of the trilobites and the shells of the brachiopods are but little altered, while those of the cephalopods and pelecypods are usually replaced by sphalerite, a difference evidently connected with the more soluble nature of the pearly shells of the nuculoids and cephalopods.

By carefully breaking away the outer enveloping volutions of a number of specimens of *Tornoceras*, the early parts of the shell were uncovered, and found to be well preserved, and therefore, suitable for study. The drawings on Plate VIII were made from the microscope, with a camera lucida.

The protoconch (figures 1, 2, Plate I) has an axial diameter of about $1{\cdot}1^{mm}$ and varies but little from this dimension among several specimens measured. The vertical diameter is a little shorter, so that the general form is that of a prolate ellipsoid. The latera are prominent, and exposed as central bosses in the umbilicus of a young shell.

* The following list is proposed as corrected references to *T. uniangulare*:
13th Ann. Rept. N. Y. State Cab., p. 98, figs. 6 (bis) (type specimen) and 6?
Pal. N. Y., vol. v, pt. ii, pl. 71, figs. 11–14 (fig. 14=type specimen), pl. 72, figs. 6, 7, pl. 74, figs. 2, 4., vol. vii, pl. 127, figs. 10, 11, 12.
Of these, pl. 71, figs. 11, 12, 13; pl. 74, fig. 4 and pl. 127, figs. 11, 12, were referred to *P. (Goniatites) discoideum*, Hall.

At what precise growth stage the umbilicus becomes closed cannot be ascertained from the material studied, but it is evidently open during the formation of several whorls. During the concrescence of the first few air chambers, while the diameter of the tube is diminishing, the tendency of the umbilicus is to enlarge rapidly. Subsequent increase in the tube and the greater involution of the whorls contract it, so that in adult specimens, it is closed, while in large and often senile individuals, a secondary deposit is made about the umbilicus, entirely obliterating it and covering the growth lines of the shell.* Evidently this formation is similar to that deposited by the dorsal lobe of the mantle in *Nautilus pompilius*.

The axial diameter of the embryo shell is somewhat greater than that of several of the succeeding air chambers. Thus, the tube, in its growth, first contracts, and does not assume the regular rate of increase until after the formation of at least the second septum. A cross section at the first septum is transversely subelliptical, slightly arcuate, with a longer diameter two and one-third times greater than the shorter. When a transverse diameter of $1{\cdot}2^{mm}$ is reached by the larval shell, the outline of a section is lunate, but the proportions of length and height are not materially changed. A section of the adjacent whorl is still more arcuate, as shown in figure 6, and in an adolescent specimen $11{\cdot}5^{mm}$ in diameter it is seen that the diametral relations have become interchanged, and that the outer whorl is elliptical in a vertical direction, and excavated by the inner whorl to nearly half its longest diameter, making the shell in all nealogic and ephebolic stages decidedly compressed in outline (figure 13).

The first septum (figures 1, 2, 4) is moderately concave, and extends nearly to the axis. The suture is simple, being nearly in a single plane, without apparent lobes or saddles. Occasionally, the internal mould shows a siphonal lobe due to the breaking away of the extremely thin filling between the siphon and ventrum, but perfect specimens determine this to be an accidental condition.

In the section represented in figure 12, the first two septa are much thicker than those immediately succeeding, a feature also noticeable on the exterior of the internal mould. Likewise, the first and second air chambers are deeper than the three or four following. With these exceptions, the septa and air chambers are generally uniform in their progression until the adult stage.

It has already been noted that the first septum is extremely simple, without apparent lobes or saddles. In the second sep-

* This feature is well represented in figure 11, Plate 127 of Pal. N. Y., vol. vii, Supplement.

tum, there is a well-developed sinus over the siphuncle, forming a rounded ventral lobe, and a broad lateral saddle, with a corresponding, though less prominent, dorsal saddle. The third and following septa present more and more sharply angular ventral lobes, until finally it is further extended by a siphonal fissure in post-nepionic stages. The lateral saddle is not so strongly curved from the fourth to the seventh suture which is quite flat, but in the eighth, a slight retral bend is observable. This evidently marks the inception of the lateral lobe. The septum is now divided into the leading members characteristic of the group, viz: a ventral lobe and saddle, a lateral lobe and saddle, a dorsal saddle and an annular lobe, although the two latter are less strongly marked than the others. Further growth merely serves to emphasize these features, until the nealogic stadium, when the ventral lobe is extended by the siphonal fissure, and a minute cone appears at the bottom of the annular lobe.

Several specimens of the protoconch give evidence of the presence of the siphonal cœcum, and show that it was probably closely appressed to the ventral wall. Figure 3 illustrates the ovoid marking on the interior of the shell, enclosing two diverging lines which apparently represent the appressed portion of the true cœcum, while the outer curved lines limit the shelly deposit of attachment. The relative diameter of the siphon at the first and for a number of succeeding chambers is much greater than in the mature shell (figures 1, 6, 13). From the beginning, it is situated close to the abdominal wall, and is nearly invariable in its character.

The embryonic shell is very thin, and almost smooth in its earlier portions; then fine revolving lines of granules appear, which become progressively more pronounced and arranged in transverse rows, between which the earliest of the concentric striæ are developed. With the increase in the strength of the striæ, the granules disappear, and are obsolescent before the protoconch is completed (figure 7). The striæ are sharp, elevated, and straight, forming a conspicuous feature of the ornamentation, until in the third or fourth whorl, when they become subdued, and finally are replaced by the fine inconspicuous and often fasciculate lines of growth which are present in the adult shell. No indication of a funnel is shown up to the completion of the first whorl (figure 10), as the striæ continue straight across the ventrum, but in the second (figure 11), the pronounced sinus in the striæ shows that the funnel had developed or, at least, had become of functional importance.

A comparison of the figures of *T. retrorsum*, v. B., var. *typum*, Sand., as illustrated by Branco (*loc. cit.* pl. v. fig. vii), with the present species shows that the former presents a more

arcuate first septum, and that the second is comparable with the third or fourth of *T. uniangulare*, clearly indicating that the development has been accelerated by the skipping of at least two phases of growth in the septa. In other characters, the two forms merely indicate differences which are probably only of specific importance, such as the more angular form of the lobes and saddles in *T. retrorsum*, var. *typum*, and the absence of the minute cone at the summit of the annular lobe.

Yale University Museum, April, 1890.

EXPLANATION OF PLATE I.

FIGURE 1.—Protoconch, showing first septum with lateral edges broken. × 18.
FIGURE 2.—Side view of preceding. × 18.
FIGURE 3.—Ventral view of protoconch with one attached air chamber, showing siphonal cœcum. × 18.
FIGURE 4.—Side view of first whorl. × 18.
FIGURE 5.—Ventral view of preceding, showing development of ventral lobe. × 18.
FIGURE 6.—Transverse section of two whorls near the protoconch. × 18.
FIGURE 7.—Ventral side of protoconch, retaining the shell. × 18.
FIGURE 8.—Ventral side of specimen with first chamber, showing surface ornaments and indication of siphonal cœcum. × 18.
FIGURE 9.—Profile of same. × 18.
FIGURE 10.—Surface ornaments on a specimen consisting of a single whorl. × 18.
FIGURE 11.—Four striæ from the second whorl of a specimen showing funnel sinus. × 18.
FIGURE 12.—Vertical section showing septa and air chambers. × 18.
FIGURE 13.—Outline of a half grown specimen. × 3.
FIGURE 14.—A series of developed septa beginning with the first, showing gradual inception and formation of lobes and saddles to the adult period represented by *j*. *a*, *b*, *c*, *d*, represent the 1st, 2d, 3d and 4th septa, while *e* and *f* represent the 7th and 8th respectively. × 9.

Specimens in Yale University Museum, from the Hamilton shales of Wende Station, N. Y., except specimen figure 13, which is from 18-Mile Creek, N. Y.

ART. IX.—*Fayalite in the Obsidian of Lipari;* by JOS. P. IDDINGS and S. L. PENFIELD.

THE Lipari islands have long been celebrated for their acid lavas and pumices; and it was for the purpose of becoming acquainted with their craters and flows of these rocks that one of the writers recently visited this far famed locality. The obsidian flows that terminated the volcanic activity which built up the craters of snow-white pumice stretch their glassy streams down the steep mountain slopes into the sea. Their upper surface presents a rough and forbidding tract of sharp angular blocks, which appear to have suffered very little change since the solidification of the lava. This portion of the obsidian is filled with small gas bubbles that give it a gray color, and a more or less banded and laminated structure.

The inflation was not sufficient to produce pumice, as in the case of the obsidian flow at Obsidian Cliff in the Yellowstone National Park.*

The spherulites and lithophysæ that occur within the lava sheets some distance from their upper surface are small. They are very abundant in places and are distributed irregularly, and also in layers. Occasionally, finely spherulitic bands render the rock lithoidal. The obsidian is jet black, but on thin edges it is very transparent, and the light gray spherulites may be seen at some depth within the rock. The hollow spherulites in the obsidian stream from the Forgia Vecchia on the east side of the island of Lipari are complex-looking bodies. At first glance they appear to be gray, hollow shells with a rudely spherical kernel at the center. Upon closer examination it is seen that the kernel is a highly crystallized spherulite with distinctly radial structure combined with many small globules. The center of the kernel is dense and gray, but the outer portion consists of a bristling mass of acicular crystals, radiating outward, together with the crystalline pellets already mentioned. The same crystals coat the inside of the surrounding shell, and in many places are continuous with those of the kernels, and are evidently the same growth. The shell is dense with a sub-vitreous luster, and has a narrow white band parallel to the inner margin. The amount of space between the kernel and shell varies considerably. In the smaller spherulites there is very little, and the whole body is clearly one spherulite consisting of a central portion with distinctly radial structure, surrounded by concentric shells of slightly different characters. The innermost of these shells is highly crystalline, white and porous, with minute spaces between the acicular crystals. The next shell is dense, gray and sub-vitreous, and is followed by a narrow white one; the outside, broader shell being dense, gray and sub-vitreous. In the larger spherulites the porous zone has become so porous or open that it forms a cavity between the central part of the spherulite and the outer, denser zones.

Within the larger cavities the white pellets are recognizable as spherical groups of tridymite, and with them are associated occasional thin tablets of fayalite, which, however, are not found in all of the spherulites.

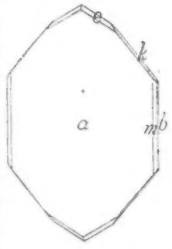
A microscopical examination of the spherulites shows that they are beautifully crystallized at the center, the radiating needles being alkali feldspar. Tridymite is also present, in places being clustered in spherical groups of minute crystals. The structure is the same as that observed in some of the

*Obsidian Cliff, Yellowstone National Park, by J. P. Iddings, Seventh Annual Report of the U. S. Geological Survey, 1888, p. 256.

spherulites at Obsidian Cliff, and described in the paper already cited. The outer shells are fibrous, the gray ones being colored by a cloudy material, which is light brown in transmitted light, and does not appear to be doubly refracting. The feldspar fibers throughout the spherulite are variously orientated in the zone of their elongation, so that they extinguish light between crossed nicols in groups at different angles to the plane of polarization, and exhibit no definite dark cross. In this respect also the spherulites correspond to those at Obsidian Cliff.

The chief interest, however, attaches itself to the fayalite crystals in the cavities, which have not been noticed heretofore. They are not abundant, but occur in several localities, having been found by the writer at Forgia Vecchia, and in the obsidian stream on Volcano, and having been noted in specimens from Monte della Guardia on the island of Lipari. In the first and second occurrences just mentioned the fayalite is perfectly fresh and transparent. In the third it is more or less altered and opaque.

The crystals of fayalite found at Forgia Vecchia are very thin plates, the largest being about 1^{mm} long, $0{\cdot}5^{mm}$ wide and less than $0{\cdot}03^{mm}$ thick. The habit of the crystals is shown in the accompanying figure. The forms which were identified are *a*, 100, $i\text{-}\bar{\imath}$; *b*, 010, $i\text{-}\check{\imath}$; *m*, 110, *I*; *k*, 021, $2\text{-}\check{\imath}$; and *e*, 111, 1. A slight variation in habit is sometimes caused by the greater development of the *e* faces. It should be noted that the prism in this occurrence is *m*, 110, *I*, and not *s*, 120, as in the fayalite from Obsidian Cliff, Yellowstone Park, and that the basal plane *c*, 001, is wanting. Very accurate measurements of course can not be expected from such very minute crystals, but by employing a strong illumination and a low ocular lens, *δ* of Websky, the following angles were measured on a Fuess goniometer, which serve perfectly for the identification of the forms. The calculated angles are derived from the axial ratio established on the fayalite from the Yellowstone National Park.*



		Measured.	Calculated.
$a \wedge e$,	$100 \wedge 111$	42° 5′	42° 27′
$e \wedge e$,	$111 \wedge \bar{1}11$	95° 38′	95° 6′
$b \wedge k$,	$010 \wedge 021$	41° 2′	40° 49′
$a \wedge m$,	$100 \wedge 110$	24° 30′	24° 38′
$m \wedge m$,	$110 \wedge \bar{1}10$	130° 35′	130° 44′

Cleavage is distinct parallel to *b*, 010. The crystals have a honey-yellow color and show no perceptible pleochroism. In

*This Journal, III, xxx, 1885, p. 58, also Seventh Annual Report of the U. S. Geological Survey, 1888, p. 271.

polarized light they give an extinction parallel to the vertical axis; and in the 45 degree position the thickest crystals exhibit an interference color which is red of the second order. In convergent polarized light an obtuse bisectrix emerges at right angles to a, 100, the plane of the optic axes being parallel to the base. The optical orientation is $\breve{a}$=c, $\bar{b}$=a and $\dot{c}$=b. Since a is the acute bisectrix the double refraction is negative. These optical properties not only agree with orthorhombic symmetry, but also with the determinations made on the Yellowstone Park fayalite.

When treated with hydrochloric acid the crystals are decomposed, and gelantinize. They contain ferrous iron, and after the separation of the iron from solution with ammonia, they yield no micro-chemical reaction for magnesia. Their chemical composition, therefore, is undoubtedly the same as that of the fayalite from Obsidian Cliff, namely: orthosilicate of iron.

The occurrence of fayalite in the hollow spherulites and lithophysæ in the obsidian of the Lipari islands, while not so abundant as in that of the Yellowstone Park, is identical. It is associated in the same manner with tridymite and alkali feldspars, and its development is unquestionably due to the same causes in the two regions.

ART. X.—*On some Selenium and Tellurium minerals from Honduras;* by EDWARD S. DANA and HORACE L. WELLS.

THROUGH the kindness of Mr. Henry S. Durden, of the State Mining Bureau in San Francisco, we have received a number of specimens of minerals containing selenium and tellurium, two of which have proved to be of unusual interest. The presence of selenium in some of them had been already determined by Mr. Charles G. Schneider before they were sent to us, but further than that the examination had not gone. The locality from which they were obtained, as Mr. Durden informs us, is the El Plomo mine, Ojojoma District, Department of Tegucigalpa, Honduras.

The mineral, to which our attention was first directed, proved upon blowpipe examination to contain selenium and tellurium, while the metals proper were absent. It presents itself in massive forms only, with indistinctly columnar structure and shows a perfect cleavage parallel to a prism of 60°. The color is blackish gray, the streak black. It is disseminated through a gangue consisting chiefly of quartz with some barite. An analysis (Wells) of the mineral proved it to contain selenium and tellurium only. The separation of

selenium and tellurium was effected by the very convenient method of Divers and Shimosé.* In carrying out this method, it was found that the selenium obtained by a single separation sometimes contained quite a large quantity of tellurium, but the latter could be readily removed by one or two repetitions of the process.

The results obtained are as follows, after deducting 65·68 per cent of gangue consisting of about 43 per cent of silica and 19 per cent of barite with a little gypsum and a trace of alumina:

Se	29·31
Te	70·69
	100·00

The mineral is, therefore, intermediate between selenium and tellurium in composition, and contains these elements in very nearly the ratio of 2 : 3; though we do not attach any importance to the ratio, for the mineral obviously represents simply an isomorphous mixture of these two elements. It is of great interest, however, since it is the nearest approach to native selenium which has yet been found in nature.† The mineral most closely allied to it is a native tellurium from Faczebaja in which Foullon found 6·7 per cent of selenium. It seems to us, therefore, to deserve to be given a somewhat prominent position and we propose to call it *Selen-tellurium*. It is interesting to note here the recent observations of Muthmann‡ showing among other new points the existence of an allotropic form of metallic selenium in hexagonal-rhombohedral crystals, closely isomorphous with metallic tellurium. Our mineral is shown by its hexagonal cleavage to belong with these, as was to have been expected.

Associated with the selen-tellurium are a few minute transparent crystals having a pale yellow color and adamantine luster, which have the appearance of tellurite. The quantity is so extremely small as to make an examination unsatisfactory and we defer the matter in the hope of obtaining additional material.

Quite distinct from the yellow crystals just mentioned, is a greenish yellow mineral which is also obviously an oxidation product and which is present more abundantly. It is best shown in two or three specimens, having the aspect of a quartzose conglomerate and containing patches of a grayish metallic mineral which proved to be nearly pure tellurium. Through this it is

* Jour. Chem. Soc., xlvii, 439.

† We pass over Del Rio's unconfirmed statement, in regard to the occurrence of native selenium in Mexico, as not deserving of serious consideration.

‡ Zeitschr. für Kryst., xvii, 356, 1890.

scattered in points and narrow veins. It is soft, with hardness from 2 to 2·5 and is easily crushed to powder. The surface, when exposed, is small mammillary and but little structure is discernible even under the microscope, although a tendency to separate into distinct scales is noted. The action on polarized light is very feeble. The mineral is intimately mixed with the gangue and it was only by using extreme care that it was found possible to separate a sufficient quantity of material for analysis, the purity of which could be regarded as beyond all question. This was finally accomplished, however, and an analysis made with the following results. Of the whole amount obtained, viz: 0·32 grams, 0·12 gr. was taken for a water determination and the remainder 0·20 gr. for the other determinations. The results, considering the small quantities used, are very satisfactory. The analysis is as follows:

			Ratio.				
Water	7·67 ÷ 18 = ·426		3·55		4·06		4
TeO_2	47·20 ÷ 157 = ·301	·315	2·62	or	3·00	or	3
SeO_2	1·60 ÷ 111 = ·014						
Fe_2O_3	19·24 ÷ 160 = ·120		1·00		1·14		1
Insol.	23·89						
	99·60						

These ratios are not quite exact, but there can be no doubt that it is a normal ferric tellurite of the composition $Fe_2O_3 . 3TeO_2 . 4H_2O$ or $Fe_2(TeO_3)_3 + 4H_2O$. The slight excess of Fe_2O_3 shown by the ratio very probably comes from the reddish ochreous material associated with it.

The calculated composition, with $\frac{1}{21}$ of the Te atoms replaced by Se, is:

Calculated for $Fe_2O_3 \frac{20}{21} TeO_2 + \frac{1}{21} SeO_2 . 4H_2O$.		Analysis Deducting Insol. Res.	
TeO_2	64·41	TeO_2	62·34
SeO_2	2·28	SeO_2	2·12
Fe_2O_3	22·97	Fe_2O_3	25·41
H_2O	10·34	H_2O	10·13
	100·00		100·00

That the mineral is a ferr*ic* tellur*ite* is evident since it gives off no chlorine when boiled with HCl, nor does it give any reaction for ferrous iron when dissolved in cold HCl.

Two other tellurium-iron minerals have been thus far described: these are Genth's* *ferrotellurite* and the *emmonsite* of Hillebrand.† Our mineral is like ferrotellurite in color, but, if the results of Genth's qualitative trial can be accepted as conclusive, his mineral was a ferrous tellurate, which sepa-

* Proc. Acad. Nat. Sci. Philad., xvii, 119, 1877.
† Proc. Colorado Sci. Soc., ii, 1885.

rates it widely from the Honduras ferric tellurite. Emmonsite corresponds in composition more closely, being also a ferric tellurite, and we were inclined at first to think that the two minerals might be identical. Through the kindness of Dr. Hillebrand we have had an opportunity to inspect the original emmonsite, and furthermore Dr. Hillebrand has made a new chemical examination of the scanty amount of material at hand, the results of which are appended to our paper. Our own examination did not extend beyond a microscopic study of the cleavage plates, but these while confirming the points made by Mr. Cross in regard to the cleavages and chief optical characters, proved that in appearance the Honduras mineral and emmonsite are widely different. Moreover, Dr. Hillebrand's recent results show that the two minerals differ both in ratio of tellurium to iron, and also in amount of water. The Honduras mineral consequently cannot be united with either of the minerals named, and although our knowledge of its physical characters is imperfect, the simplicity and exactness of the chemical formula shows that it deserves to rank as a definite mineral species. We propose, therefore, to call it *Durdenite* after the gentleman to whose kindness we are indebted for all the material we have had to use.

Note on Emmonsite by Dr. W. F. Hillebrand.

I have attempted a re-analysis of emmonsite with the extremely limited quantity belonging to Mr. Cross, which he kindly consented to sacrifice for the purpose. Unfortunately the analysis was not entirely successful, but what was done upholds the correctness of my former analysis and seems to prove that the two minerals are distinct. The weight taken for analysis was ·0764 grams. The water was determined in this by heating in a boat with a plug of dry sodium carbonate filling the tube in front, and collecting the water in a calcium chloride tube. The weight found was ·0032 grams, or 4·2 per cent. This, under the circumstances, is as near as could be expected to my original determination (3·28 per cent), which was made on less pure material, and shows that emmonsite is distinct from the Honduras mineral, which has over 10 per cent of water. After dissolving the ignited mineral, a rather considerable portion of the solution was unfortunately lost, but the relation of the iron and tellurium in what remained was estimated; the result being $Fe_2 : Te = 1 : 3{\cdot}75$. This is very near that originally found, i. e., $1 : 3{\cdot}65$. I did not detect any zinc in this analysis, which is confirmatory of the opinion formerly expressed that it was present as an admixture in some form.

In regard to the behavior of emmonsite on heating it may be added that even at as low a temperature as 100° C. it becomes

brownish, but regains its green color on cooling without having suffered loss in weight. In an unpowdered condition it decrepitates rather violently on further heating, and, as originally stated, fuses readily to a red-brown liquid. In regard to the evidence as to the condition of oxidation of the iron and tellurium in emmonsite afforded by boiling the mineral with hydrochloric acid, I would add that my former experiment was carefully made and the products of distillation were collected in a solution of potassium iodide. No evolution whatever of iodine was observed. While this would not prove the entire absence of a ferrous tellurate, it does prove conclusively, as indicated in my original paper, that the mineral is chiefly a ferric tellurite. This being true, it would be reasonable, even without other evidence, to conclude that the mineral is simply a ferric tellurite and not a combination of ferric tellurite with ferrous tellurate.

Washington, May 31, 1890.

Art. XI.—*On Connellite from Cornwall, England;* by S. L. Penfield.

The rare Cornish mineral, Connellite, was first described as a new species by Prof. Connell, who presented, in 1847, at a meeting of the British Association for the Advancement of Science,* a short communication in which he stated that from qualitative tests he had proved it to be a sulphato-chloride of copper containing water. The name Connellite was first given by Prof. J. D. Dana, in the third edition of his Mineralogy, 1850. In the fifth edition of his Mineralogy he also gives a reference to the mineral as early as 1802, by Rasleigh,† who calls it a "copper ore of an azure blue color, composed of needle crystals," from Wheal Providence. In 1863 Maskelyne‡ published a description of the crystals, in which he determined the form as hexagonal, habit slender prismatic, with holohedral pyramidal terminations. Owing to their small size (crystals being not over $\frac{1}{20}$ inch in diameter), he was unable to measure the angle of the terminal faces on the ordinary reflecting goniometer, but by means of a microscope attachment to his goniometer he was able to measure them with a fair degree of accuracy. He identified two prisms, a pyramid of the first order, and a di-hexagonal pyramid. He gives two figures, one of which is copied in the fifth edition of Dana's Mineralogy, the other representing a simpler combination of prism of the second with pyramid of the first order.

* Report of the British Association for 1847. † Brit. Min., ii, 13, pl. 12, f. 1, 6.
‡ Phil. Mag., IV, xxv, 39.

The mineral is one of special interest to the author owing to its apparently close relation to the newly described Spangolite,* as well as the general interest which one always has for such a rare and beautiful mineral, which has been for so many years mentioned and partially described in mineralogical literature. Fortunately Prof. Brush had in his cabinet a specimen of the mineral, labeled Camborne in Cornwall, which he had obtained from the Mineralien-Niederlage in Freiberg and which he generously placed at my disposal. The specimen was composed chiefly of octahedral cuprite, in the cavities of which the connellite had deposited, mostly in radiated groups; malachite and agate were also associated with it. It did not at first seem possible that enough material could be obtained for making an investigation, but on breaking into the specimen additional cavities were found which contained crystals. Owing to the beautiful blue color of the mineral it could readily be distinguished from the cuprite, and by careful selecting nearly 0·05 gram was obtained on which not the least trace of impurity could be detected when examined with a strong magnifying glass. The specific gravity of two of the pieces was taken in the barium-mercuric iodide solution, and found to be 3·364. There was, therefore, the possibility of obtaining still more of the mineral by crushing and sifting all of the material which had been picked over and separating by means of the heavy solution. The separation presented some difficulties, as the cuprite was somewhat attacked by the heavy solution, and the malachite varied in specific gravity (owing probably to impurities), some of it being almost exactly like the connellite; the mineral was, however, separated from the heavier cuprite and lighter agate, but still contained malachite, from which it was further separated by hand picking. The powder was repeatedly brushed from one watch glass to another and examined in a strong light with a lens, so that every bit of malachite which might perhaps be attached to the connellite might be seen and removed. This repeated examination of the powder assured the author that the material which he had for examination was of exceptional purity. Altogether 0·074 gram of the pure material was obtained. Before commencing the chemical analysis the crystals were carefully examined. The habit agrees well with the general description of Maskelyne; most of the crystals are slender prismatic, terminated by a pyramid of the opposite order. Crystals are seldom over 0·15^{mm} in diameter, the largest are in slightly divergent groups, and it was not only difficult to isolate a single terminated individual, but also to adjust it on the goniometer. In three cases the adjustment was made so that the terminal angle of the pyramid ($10\bar{1}1 \wedge 01\bar{1}1$) could be

* This Journal, III, xxxix, 370.

measured with the following results: 49° 26′, 49° 50′ and 49° 42′. The reflections were good, but of course faint, owing to the small size of the faces. Maskelyne gives for the same angle 47° 10′. The zone $2\bar{1}\bar{1}0$, $01\bar{1}1$ and $\bar{2}110$ was also adjusted on the goniometer in which the pyramid was found to be at right angles to the prism of the second order and finally one prismatic zone was measured in which the angles approached very closely to 60°. Using the mean angle of $p \wedge p$ ($10\bar{1}1 \wedge 01\bar{1}1$) = 49° 39′, the length of the vertical axis $\dot{c} = 1{\cdot}3392$ can be calculated. This is probably obtained from more exact measurements than those of Maskelyne. Among the many fragmentary crystals examined under the microscope, the majority had the simple habit of prism and pyramid of the opposite order, a few only showed the combination of prism and pyramid of the same order, while still others were slender and tapering, in habit like an Alston Moor aragonite crystal, but usually terminated at the very end by the ordinary pyramid. No crystals were observed like those described by Maskelyne, showing combinations of the two prisms or a dihexagonal pyramid.

Hardness about 3. Specific gravity as stated above, 3·364. The crystals are transparent and of a beautiful dark blue color, the fine powder is a pale greenish blue. Crystals show under the polarizing microscope parallel extinction and strong positive double refraction, determined on thin prismatic crystals by means of the quartz wedge: they exhibit no perceptible pleochroism, which agrees with the statement of Maskelyne. No distinct cleavage was detected.

The chemical analysis was made with great care on 0·0740 gram. This seems a very small amount for the purpose, but I was prepared to take advantage of the experience which had been gained in the analysis of spangolite, and as no rare or unusual constituents were met with, and as the analysis went on without any mishap I am prepared to place great confidence in the results, which are as follows:

		Ratio.		Spangolite.
SO_3	4·9	·061	1·00	10·11
Cl	7·4	·208	3·42	4·11
CuO	72·3	·911	15·00	59·51
H_2O	16·8	·931	15·34	20·41
Loss at 100° C.	·4			Al_2O_3 6·60
	101·8			100·74
O equivalent to Cl	1·7		O eq. to Cl	·72
	100·1			99·82

The ratio here is not very satisfactory except between SO_3 and CuO, with H_2O slightly in excess. If, however, we assume that some OH is isomorphous with the Cl and calculate enough

OH so that when added to the Cl it will bring the ratio up to the first whole number, the analysis will be as follows:

		Ratio.		
SO_3	4·9	·061		1·00
Cl	7·4	·208	·243	4·00
OH	·6	·035		
CuO	72·3	·911		15·00
H_2O	16·5	·913		15·04
Loss at 100° C.	·4			
	202·1			
O equivalent to Cl and OH_1	2·0			
	100·1			

With this interpretation the ratio is very exact, and from the repeated instances in which Cl and OH mutually replace one another it seems best to make this assumption to explain the analysis. The formula can then be written $Cu_{15}(Cl . OH)_4 SO_{16}, 15H_2O$, although it is of course probable that all of the Cu which is not in combination with Cl and SO_4 is combined with hydroxyl. The compound is very similar to spangolite in composition, an analysis of which is given above for comparison, both minerals being very basic sulphato-chlorides. In spangolite, moreover, the closest relation was found between SO_3, Al_2O_3 and CuO, while Cl was slightly deficient and H_2O high, and it was also stated in discussing that analysis that the ratios could be made almost exact by assuming, as in this case, that a little OH is isomorphous with the Cl. The method of analysis was on the whole like that employed in the analysis of spangolite. The air-dry powder lost very little by drying in a desiccator over H_2SO_4 or in an air bath at 100° C. For determining the water the mineral was weighed in a platinum boat, covered with dried Na_2CO_3 and ignited in a combustion tube, the water being collected in a weighed chloride of calcium tube: it was found to be neutral. Before making the experiment on the mineral a blank trial was made in which the chloride of calcium tube gained only ·0002 gr., showing that dried Na_2CO_3 can be handled quickly in the air without taking on any appreciable quantity of moisture. The greatest pains was taken with the SO_3 determination: before filtering off the precipitated $BaSO_4$ the solution containing the precipitate was repeatedly evaporated with HCl to remove as far as possible all HNO_3. After filtering off the $BaSO_4$ the filtrate was again evaporated to dryness, taken up in very dilute acid and water and the least trace of $BaSO_4$ filtered off. The $BaSO_4$ precipitate originally weighed 0·0110 gr. after purifying in the ordinary way by fusion with Na_2CO_3 and reprecipitating it weighed 0·0103 gr., showing that the first precipitate was nearly pure, and as there is some chance of loss during the manipulation of

so small quantities the first weight was used in the analysis. The very small percentage of SO_3 is certainly remarkable. Finally, the last filtrate, after precipitating the copper with H_2S, was evaporated to dryness, ignited to expel the excess of H_2SO_4, the residue dissolved in water and tested with ammonia, ammonium sulphide, ammonium oxalate and sodium phosphate, but as no precipitates were formed it was assumed that everything had been precipitated from the solution. The weighed AgCl and Cu_2S were found to be pure.

Pyrognostics and chemical tests.—Connellite fuses before the blowpipe at about 2 to a black shining globule, coloring the flame green. Heated in the closed tube it gives abundant water, which has a strong acid reaction. Insoluble in water, but soluble in dilute acids, the solution giving with barium chloride a slight precipitate of $BaSO_4$.

Mineralogical Laboratory, Sheffield Scientific School,
New Haven, May, 1890.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Chemical character of Beryllium.*—In consequence of the position of beryllium as a typical element in the periodic system, Krüss and Moraht have made an exact study of its chemical characters. The oxide was prepared from Arendal leucophane, by acting on the finely pulverized mineral with sulphuric acid in excess, the operation being conducted in a platinum dish. After driving off the excess of acid, the mass was treated with water, and the solution added to one of ammonium carbonate in excess, in which the precipitate at first formed was dissolved. After ten days standing, the filtrate was boiled, whereby a precipitate of beryllium oxide was obtained, containing some alumina and iron oxide. To purify it the beryllia was dissolved in hydrochloric acid, precipitated with ammonia and digested with ammonium carbonate solution, in quantity insufficient for complete solution. The solution after ten days standing was filtered and steam blown through it till almost all the beryllium oxide was thrown down. The last trace of iron was removed by adding ammonium sulphide to the ammonium carbonate solution, allowing it to stand two days, filtering and boiling. The ignited precipitate was snow-white and dissolved in hydrochloric acid yielding a colorless solution. To prepare metallic beryllium the authors at first heated a mixture of the oxide and metallic magnesium in a porcelain crucible; but the beryllium obtained was contaminated strongly with silicon. They then reduced potassium-beryllium fluoride with sodium in a steel crucible, the re-

duced metal being protected from contact with the crucible. On treating the mass with water small hexagonal crystals of beryllium were obtained mixed with pulverulent metal and oxide. To determine whether beryllium oxide could act as an acid oxide and form beryllates the freshly precipitated hydroxide was digested in alcoholic solution of potassium hydroxide until it was saturated, care being taken to exclude carbon dioxide. On evaporation over sulphuric acid, a white silky mass was obtained which gave a formula closely approximating $Be(OK)_2$. To determine the basicity of beryllium oxide, absolute alcohol was saturated with sulphur dioxide gas, and pure, recently precipitated beryllium hydroxide was dissolved in it to saturation. On evaporation over sulphuric acid, a white crystalline residue consisting of minute hexagonal plates was obtained which on analysis corresponded to the formula $BeSO_3$. With boric acid, a borate $Be_5B_2O_8$ was obtained.—*Ber. Berl. Chem. Ges.*, xxiii, 727, Mch. 1890. G. F. B.

2. *On the estimation of the Molecular mass of Colloids by the method of Raoult.*—Sabanéeff has made a series of experiments to determine the molecular mass of certain colloid substances by means of the freezing points of their aqueous solutions. Colloidal tungstic acid, for example, dried at 200° and containing 2·57 per cent of water, corresponding to the formula $H_2W_3O_{10}$ which requires 2·52 per cent, has a molecular mass calculated from the observed lowering of the freezing point, varying between 677 and 995; while that represented by the formula $H_2W_5O_{16}$ is 714. Colloidal molybdic acid forms minute hygroscopic plates, which dried over sulphuric acid for several weeks still contain 6·99 per cent of water. It dissolves with difficulty in water and produces a lowering of the freezing point corresponding to a molecular mass of 620; that required by $(MoO_3)_4$ being 576 and that corresponding to tetra-molybdic acid $H_2Mo_4O_{13}$ being 594. For glycogen the molecular mass found was as a mean 1585, corresponding to the empirical formula increased tenfold $(C_6H_{10}O_5)_{10}$, which requires 1620. Dried at 115°, however, this substance possesses a molecular mass one and a half times less. The lowering of the freezing point produced by colloidal silicic acid was so slight that the values obtained all came within the limits of observational errors. Colloidal iron hydroxide could not be obtained free from chlorine; the purest solution containing one molecule of $FeCl_3$ to 116 molecules $Fe(OH)_3$. On the assumption that the molecular mass of the hydroxide is so great that its influence in producing the slight depression of the freezing point observed may be neglected, the author calculates from the observed data a molecular mass of 300 corresponding to the formula Fe_2Cl_6 which requires 325.—*J. Russ. Phys. Chem. Ges.*, 1889, 515; *Ber. Berl. Chem. Ges.*, xxiii, (Ref.) 87, Mch. 1890. G. F. B.

3. *On the Color of Fluorine and on its Spectrum.*—Moissan has examined the color of fluorine as seen through a platinum tube

50 centimeters long, having its ends closed with transparent plates of fluor spar. Under these circumstances the gas appears of a distinctly greenish-yellow color, less strongly pronounced than that of chlorine and inclining rather more to yellow. If a little water be allowed to enter this tube full of fluorine, hydrogen fluoride is at once formed and the oxygen is set free in the form of ozone, in a condition of such concentration that the contents of the tube become of a deep indigo-blue color. In order to obtain the spectrum of fluorine, sparks were taken in an atmosphere of this gas contained in a platinum tube, between gold or platinum electrodes. In the red region of the spectrum, the author found thirteen well-defined lines having the following wave-lengths: 749, 740, 734, 714, 704, 691, 687·5, 685·5, 683·5, 677, 640·5, 634 and 623. By a comparison of silicon chloride and fluoride Salet had already observed lines of wave-lengths 692, 686, 678, 640, 623, which he attributed to fluorine.—*C. R.*, cix, 937; *Ber. Berl. Chem. Ges.*, xxiii, (Ref.) 140, Mch. 1890.

G. F. B.

4. *On the Preparation of Hydrazine from Aldehyde-ammonia.*—Curtius and Jay have described a simple method of obtaining hydrazine from aldehyde-ammonia $CH_3 . CH . OH . NH_2$. By the action of sodium nitrite upon a cold saturated solution of aldehyde-ammonia in water feebly acid, the nitrosoamine of a base $C_5H_{11}O_2 . CH . NH$, which the authors call paraldimine results, the nitroso-paraldimine itself having the formula $C_5H_{11}O_2 . CH . NNO$. If a little moist hydrogen chloride gas be passed into the ethereal solution of this nitrosoamine, it yields paraldimine hydrochloride $C_5H_{11}O_2 . CH . NH . HCl$, in the form of clear colorless needles. These dissolved in ether and treated with silver oxide yield the free base paraldimine as a mobile colorless liquid, with an odor recalling that of paraldehyde, and which solidifies to a mass of crystals in a freezing mixture. By the action of zinc dust and glacial acetic acid on the nitrosamine, amido-paraldimine $C_5H_{11}O_2 . CH . NNH_2$ is formed; and this when boiled with dilute sulphuric acid, yields paraldehyde and hydrazine sulphate:

$$C_5H_{11}O_2 . C\begin{cases} H \\ NNH_2 \end{cases} + H_2O + H_2SO_4 = C_5H_{11}O_2 . C\begin{cases} H \\ O \end{cases} + N_2H_4 . H_2SO_4$$

By distillation with alkalies hydrazine hydrate is obtained from the sulphate. The nitroso-paraldimine may be converted directly into hydrazine sulphate by the action of zinc dust and sulphuric acid; but the yield is small owing to the fact that the reduction is liable to go too far.—*Ber. Berl. Chem. Ges.*, xxiii, 740, Mch. 1890.

G. F. B.

II. Geology and Mineralogy.

1. *Post-Tertiary Deposits of Manitoba and the adjoining territories of Northwestern Canada;* by J. B. Tyrrell, of the Geological Survey of Canada. (Bulletin of the Geological Society of America.)—The district treated of in this paper com-

prises the northern extension of the prairies of Dakota and Montana lying within Canadian territory, and consists largely of the drainage basins of the Saskatchewan and Assiniboine Rivers stretching westward from the Archæan nucleus to the Rocky Mountains. This region is almost entirely underlain by clays and sands of Cretaceous or Laramie age. But some Miocene and Pliocene conglomerates, composed of quartzite pebbles from the Rocky Mountains extend as far east as long. 107° 15′, and these conglomerates furnish a secondary source of supply for many of the quartzite pebbles of the drift.

The whole region, with the exception of four of the higher points near its southwest corner, is covered with a deposit of till that varies greatly in thickness, being especially affected by the many inequalities in the surface of the underlying older beds. The till is, as usual, an unstratified deposit largely of local origin, but having included in it a considerable amount of material derived from the northeast. In the more western parts of the Canadian plains it may be subdivided into two divisions, separated by a distinct interglacial formation, showing clear evidence of a retreat and a re-advance of the continental glacier, but for Manitoba proper the evidence of an interglacial period is not so clear.

The fact is also again clearly pointed out that there is a narrow belt of country stretching along the foot of the Rocky Mountains from which the till is absent and which has never been overridden by the continental glacier.

Intimately associated with the till are a number of terminal moraines similar to those that have been traced out by several American geologists in Minnesota, Wisconsin and farther east, which appear to extend in approximately parallel lines in a northwesterly and southeasterly direction across the plains, beginning on the east with the Riding and Duck Mountains and extending westward to the Hand Hills and the western end of the Cypress Hills. No terminal moraine is to be seen along the western edge of the till-covered area, but the drift gradually thins out and disappears. The theory is advanced that isolated lakes may, for short intervals of time, have occupied the space between the icefoot and the eastern flanks of the mountains, being hemmed in to the north and south by local glaciers moving eastward.

The direction of flow of the continental glacier has been traced out to some extent. In the great Lake Winnipeg Valley east of the Duck and Riding Mountains the ice flowed southeastward in the direction of the trend of the valley. A similar remark holds good for the valley of the Upper Assiniboine River, and it is quite possible that this direction may have been maintained all the way across the plains, the ice leaving the Archæan in a southwesterly direction, and gradually sweeping round to the southeast. In Lake Winnipegosis many of the islands are stated to be of the nature of Drumlins, lying with their long axes parallel to the direction of glacial striæ.

The Duck Mountain is shown to be of particular interest as its summit is composed entirely of morainic debris, and after the retreat of the continental glacier the summit of this moraine became itself a collecting ground for the snow from which glaciers flowed down the valleys of the surrounding slopes. A few kames are also recorded as occurring along with this latest stage of glaciation.

Overlying the till throughout extensive areas are stratified alluvial deposits that have been laid down in the beds of extinct Post-glacial lakes. A marked feature of these beds is the absence of fossils of any kind. The positions of some of these lakes is indicated, one or more lying near the headwaters of the Saskatchewan River, one east of the Missouri Coteau, and one on the upper Assiniboine, but the largest occupied the basin of Lake Winnipeg and has been named by Mr. Warren Upham, Lake Agassiz. The shores of this lake have been traced northward to lat. 53°, and how much farther north they extend is not known.

Mr. Tyrrell in answer to questions stated that the evidence at present at hand appeared to indicate that the preglacial drainage of the Winnipeg basin was northward rather than southward, and that the isolated bowlders seen on the surface of the plains had probably been carried to their present position within the ice of the glacier itself, and not beneath it, as had been the case with the great mass of the till.

2. *8th Annual Report of the Director of the U. S. Geological Survey*, 1886–87. — The following are Papers in this Report issued separately.

(1.) *The Trenton Limestone as a source of Petroleum and inflammable gas in Ohio and Indiana;* by EDWARD ORTON. 180 pp.—The Report of Prof. Orton is a full and thorough treatment of the subject of petroleum and gas from the Trenton limestone. The facts are among the marvelous in science, and they are here ably presented and discussed both from a geological and economical point of view. Mr. Orton's paper in the last volume of this Journal is in illustration of one branch of this subject.

(2.) *The Geographical Distribution of Fossil Plants;* by LESTER F. WARD. 300 pp.—Mr. Ward states in his opening sentence that this paper is intended as a contribution to the Sketch of Paleobotany which appeared in the Fifth U. S. G. S. Annual Report. That paper was written as an introduction to a larger work dealing exclusively with the literature of the science, and proceeding primarily from a bibliographical standpoint. This paper continues the subject "without departing from the chiefly bibliographical method," while at the same time bearing on the geographical distribution of fossil plants inasmuch as the bibliography is presented under geographical divisions, commencing with Great Britain. Mr. Ward makes the bibliography historical for each country as regards the developments in paleobotany, gives copious notes on the various works mentioned, and points out the bearing of discoveries in solving the various questions

that have been successively under consideration. The paper has involved a vast amount of labor in its preparation, and will be of great value to all interested in the department. The localities in the United States of fossil plants, and the geological periods of the plants of each, are presented in colors on a map.

(3.) *Geology of the Lassen Peak District;* by J. S. DILLER. 32 pp.—Mr. Diller has commenced his study of the geology of the Cascade Range with that of the Lassen Peak district, and here gives an account of the latter region—its general features, stratigraphical structure, and upheavals in connection with the structure of the Sierras and their relation to volcanic action in the district: The formations described are the Auriferous slates, Carboniferous limestone and serpentine; the Chico beds of the Cretaceous and the Miocene. The important conclusions with regard to the faults and constitution of the Sierras, reached by Mr. Diller, are briefly noticed on page 152 of vol. xxxiii of this Journal, 1887.

3. *Bulletin of the Geological Society of America*, vol. 1.—A list of the papers published in separate parts constituting the first volume of the Geological Society of America is given, so far as then issued, on page 402 of the last volume of this Journal. There have also appeared papers by J. B. Tyrrell on the Post-Tertiary deposits of Manitoba and the adjoining territories of Northwestern Canada (an abstract of which is given on page 38); R. W. Ells, the Stratigraphy of the Quebec Group (reviewed in the last volume of this Journal by C. D. Walcott); T. C. Chamberlin, some additional evidences bearing on the Interval between the Glacial Epochs; H. S. Williams, the Cuboides zone and its Fauna, a discussion of methods of Correlation; E. Brainard and H. M. Seeley, the Calciferous formation in the Champlain Valley with a supplement on the Fort Cassin Rocks and their fauna by R. P. Whitfield. The volume closes with the Proceedings of the Annual Meeting held at New York, December 26, 27, 28, 1889, by Prof. J. J. Stevenson, Secretary.

The titles of the papers and the names of their authors are sufficient indication that the volume is one of unusual importance as regards American geology, giving a long step of progress to the science. There are several which would be noticed particularly in this place if space allowed.

4. *The Salt Range in India.*—Dr. WM. WAAGEN, in the Memoirs of the Geological Survey of India, Ser. xiii, on the Salt Range, vol. iv, Part 1, 1889, points out that there is distinct stratigraphic unconformability in the range at the base of the Carboniferous. Another unconformability exists above the Neocomian and below the beds containing *Cardita Beaumonti*, to which period the Deccan traps are referred.

5. *The Collection of Building and Ornamental Stones in the U. S. National Museum.* A Handbook and Catalogue, by GEORGE P. MERRILL, Washington, 1889 (Rep. Smithsonian Instit., 1885–86, Part II, pp. 277–648).—The collection of building and

ornamental stones of the National Museum upon which the present work is based numbers nearly 3000 specimens. To a large extent it was brought together through the efforts of the late Dr. George W. Hawes, but his work upon it was interrupted by his early death and it has been taken up and ably prosecuted by Mr. Merrill. With the advantage of this large amount of material the author has prepared a very useful manual of American building stones. He gives the chief localities, the mode of occurrence, method of quarrying and working with numerous illustrations, with notes on the effects of weathering, means of preservation, and other related points. The closing chapter gives a concise summary of similar stones from other countries. A series of appendices give tables showing the specific gravity, strength per square inch, etc., also composition, price, and so on.

6. *Annotated List of the minerals occurring in Canada*, by G. CHRISTIAN HOFFMANN, Montreal, 1890 (Trans. R. Soc. Canada, vii (3), pp. 65–105, 1890).—This is a carefully prepared list of Canadian minerals with notes on the important localities. The species are arranged alphabetically and are about 280 in number. An interesting occurrence noted is that of bournonite from Marmora township, Hastings Co., and Darling township, Lanark County.

7. *On the Hygroscopicity of certain Canadian Fossil Fuels;* by G. CHRISTIAN HOFFMANN, Montreal, 1890 (Ibid., pp. 41–55).—The author has carried through an elaborate series of experiments with a series of Canadian fuels from anthracite to peat, showing the amount of water present in dry coal, in saturated, the loss in dry air, and the amount reabsorbed in a moist atmosphere. Some of the results are shown in the following statements:

Lignites (and peat) retain	2·5	—	5·0	p. c.	and reabsorb	10·0	—	14·5	p. c.	water.
Lignitic coals	" 1·0	—	2·0	"	"	" 6·5	—	9·0	"	"
Coals	" 0·1	—	1·0	"	"	" 1·5	—	6·0	"	"

8. *Ninth Annual Report of the State Mineralogist of California*, WILLIAM IRELAN, Jr., for the year ending December 1, 1889. 352 pp. Sacramento, 1890.—Some of the subjects discussed at length in this report are the refining and coining of precious metals by S. Gumbinner; the auriferous gravels of California by J. H. Hammond, with numerous sections and excellent illustrations; river mining by R. L. Dunn; on clays by W. D. Johnston; on pottery by Linna Irelan, etc.

9. *A Course in Determinative Mineralogy;* by JOHN EYERMAN. Easton, Penn., 1890.—This is a brief concise series of tables including chiefly the minerals of economic value, arranged first according to metallic or non-metallic luster and subdivided by blowpipe and chemical reactions. The chemical tests chosen have the advantage that they throw together the species which are allied in composition, e. g., those containing zinc, copper, etc., and hence tend to instruct the student as well as guide him in the determination of species.

10. *Giornale di Mineralogia, Cristallografia e Petrografia.* Diretto dal Dr. F. Sansoni. Vol. I, Fasc. 1. Milan, 1890. (Ulrico Hoepli.)—Mineralogists will be interested in the establishment of a new journal in Italy devoted to Mineralogy, Crystallography and Petrography. It is published at Milan under the able editorship of Dr. Francesco Sansoni, of the University of Pavia, well known as an active worker. The first number contains an exhaustive article by Artini upon the Sardinian leadhillite, with two plates, one by Sansoni upon the crystallography of a series of organic compounds, and others by Boeris, Tognini Melzi, besides notes and reviews.

III. Botany and Zoology.

1. *Die natürlichen Pflanzenfamilien*, Nos. 39 and 40.—We have had frequent occasion to call the attention of our readers to the many excellencies of this comprehensive work under the editorship of Professors Engler and Prantl. These numbers latest at hand justify fully all words of commendation we have bestowed upon the treatise. The engravings are clear and very telling, and, as in previous numbers, for the greater part, original. Schönland treats of the Order Candolleacæ, Höck, of Calycereæ, and Hoffmann, of Compositæ. In No. 40, Wille takes up, with a good degree of fullness, certain of the lower Algæ.

It gives us pleasure to urge upon our readers the request made by the editors, that persons who possess pictures which exhibit the characteristics of type-plants will kindly lend them for the purpose of having them reproduced as illustrations in the work.

G. L. G.

2. *Zoe, a Biological Journal.* San Francisco, published monthly ($2.00 per annum).—One can hardly help wishing that the founders of this new journal might have fixed upon some name more attractive. Aside, however, from its name, this first number of the new journal is attractive and promises well.

Restricting our notice to the botanical articles, we may call attention to the following. Dr. Harkness leads off with a well-considered paper on the Nomenclature of Organic Life. His views are conservative, and, we may say, conciliatory. We wish sincerely that his paper might find a larger circle of readers than it is like to have in the initial number of a new magazine. Mr. Brandegee speaks of an arborescent *Polygala*. In the cañons of the Sierra de Laguna, Lower California, *Polygala apopetala* "acquires its greatest development, and becomes a small tree, having a trunk and spreading top, and equaling in height the surrounding *Acacias* and *Lysilomas*." Mr. S. B. Parish has the first part of a paper on the naturalized plants of Southern California. His views in regard to discriminating between native and naturalized plants are sound, and, if carried out further in his work, in subsequent communications, will result in giving us information of the highest value.

Mrs. Brandegee furnishes interesting notes in regard to *Dodecatheon Meadia*. She proposes to place the different forms provisionally under four varietal heads. Mr. Brandegee sends a short note about a forest of "Cardon," the Mexican name for two species of *Cereus*, notably *C. Pringlei*. Mr. Vaslit, speaking of the genus *Crossosma*, is inclined to regard *C. Bigelovii* a depauperate form of *C. Californicum*. The journal contains a brief review of recent literature, and also short but interesting reports of meetings of the California Academy of Sciences, and of the San Francisco Microscopical Society.

It is a pleasure to welcome this carefully edited journal. We hope that it will do for the Pacific coast what is so well done in our nearer west by the Botanical Gazette and by the Bulletin of the Torrey Botanical Club, on the Atlantic coast. G. L. G.

3. *Deep-sea Mollusks and the conditions under which they exist;* by WM. H. DALL. Presidential address before the Biological Society of Washington.—The questions considered by Mr. Dall bear on the characteristics and evolution of deep-sea life, and have great interest, although, as Mr. Dall says, "the exploration of the deep-sea faunas has only begun." The conclusion of Tornoe that carbonic acid exists in the abyssal waters only in combination is questioned on the ground of the common occurrence of eroded shells. It may be questioned also on the ground of animal respiration in the depths, and probably also on that of decomposition, which would make free carbonic acid to be at least temporarily present; and considering that no plants exist sufficient to use up the carbonic acid thus evolved the excess of carbonic acid through the depths in some form must ever be on the increase. Mr. Dall states that of the Mollusks the groups that in shallow waters are phytophagous, live in the deeps chiefly on foraminifera, which they swallow in immense quantities, and he attributes to this the larger size of the intestine, the smaller teeth and jaws, and other characteristics; for there is very little food in a given mass of them in proportion to that in algæ. The carnivorous mollusks are the prevailing kinds; but the abyssal species, Mr. Dall states, may get all the food they want from the pelagic life that descends at death from above, without preying on one another. The shells are not drilled, or otherwise marked with evidence of attack by other mollusks. He gives facts respecting the fishes of the bottom which show that they live on mollusks and make large shell heaps. According to Professor Verrill, sea-urchins have been brought up with shells in their stomachs, and star-fishes with sea-urchins inside; so that depredations are not wholly absent from the deep seas. Mr. Dall observes that in deep-water mollusks the layer of aragonite of the shells are thinner than in those of shallow water; the spines of the Murices more delicate as if it were a character that was fading out because unnecessary; the sculpturing is that which strengthens in order to adapt to the pressure at the bottom; the operculum is generally horny and to a large extent absent; the

shells have often a protective epidermis and probably against carbonic acid. Of the abyssal species in the collections of the Blake, 28 per cent belong to the three families *Pleurotomidæ*, *Ledidæ* and *Dentalidæ*. The number of Brachiopods in the *Littoral*, *Archibenthal* (along the continental slopes), and *Abyssal* areas are respectively, 8, 12, 3; of Pelecypods, 98, 114, 31; of Scaphopods (genera Dentalium and Cadulus), 17, 28, 12; of Gastropods, 280, 222, 83. Of these, there are common to all three areas, 32 Gastropods, 5 Scaphopods, 10 Pelecypods and 2 Brachiopods. J. D. D.

IV. Miscellaneous Scientific Intelligence.

1. *Le Glacier de Aletsch et Le Lac de Märjelen.*—Prince Roland Bonaparte. 26 pp. 4to. December, 1889. Paris.—This memoir is devoted especially to the Aletsch Glacier lake. It is situated on the left side of the glacier about 800 meters from the Eggischhorn and between this summit and the Strahlhörner. Along side of the glacier, where the basin is wall-sided on account of the melting by the water, the depth is 50 meters. The lake has had frequent discharges in consequence apparently of the movements of the Aletsch glacier. The last took place in September, 1887, and was complete in 10 hours. It began on the first by a lowering of the level of 0·15 meter on September 1st, of 1 meter on the 2d, 2 meters on the 3d, and then on the 4th, the whole disappeared. It was half full again on the 19th. The recorded times of earlier discharges are: August, 1885; August, 1884; July, 1882; January, 1883, but was full again the next July; July, 1878; August, 1874; August, 1873, complete in 8 hours; August, 1871; August, 1864; August, 1859; August, 1840; August, 1820; August, 1813. Partial changes occurred also at other times. The discharge of the lake is a great calamity for the valley of the Rhone, which valley the waters reach near Brigue. The waters descend usually without a previous warning, and carry destruction to the cultivated fields on the way. The basin of the lake is an old moraine. At high water the height of the lake is 2367 meters; its area is 552,400 meters square.

It is proposed to lower the lake 12½ meters by a canal taking the waters above this level—rather more than half—into the valley of the Viesch. This would diminish greatly, but not prevent, the flood from a sudden discharge.

2. *Stone implement at New Comerstown, Ohio.*—Much interest is excited in Northern Ohio by the recent discovery of a typical paleolithic implement in the glacial terrace of the Tuscarawas River at New Comerstown, Ohio. The implement is made of the peculiar black flint which occurs in the "Lower Mercer" limestone of that region, and is four inches long, two wide, and one and a half thick at the larger end, and chipped on both sides all around the edge. The discovery was made by Mr. W. C. Mills, of New Comerstown, on Oct. 27, 1889. But its sig-

nificance was not fully understood until a visit to the place by Professor G. F. Wright and a party of friends from Cleveland on the 11th of April. The glacial terrace is here thirty-five feet above the flood-plain of the river, and the implement was found by Mr. Mills in undisturbed gravel fifteen feet below the surface. Additional interest pertains to this discovery because of the previsions made by Mr. Wright of such discoveries in this valley immediately after his survey of the region in 1881, and reported at considerable length in this Journal, July, 1883, p. 44.

3. *Knowledge, an illustrated Magazine of Science, simply worded, exactly described.* 20 pages 4to.—An excellent periodical, popular but accurate in its science, and fully illustrated. The number for May contains a paper by R. Lydekker, on pouched mammals, well illustrated, and one by A. C. Ranyard, on the great bright streaks which radiate from some of the larger lunar craters, illustrated by an admirable photo-engraved plate from a photograph taken with the great Refractor of the Lick Observatory, besides others of much interest, with book notices and miscellaneous notes.

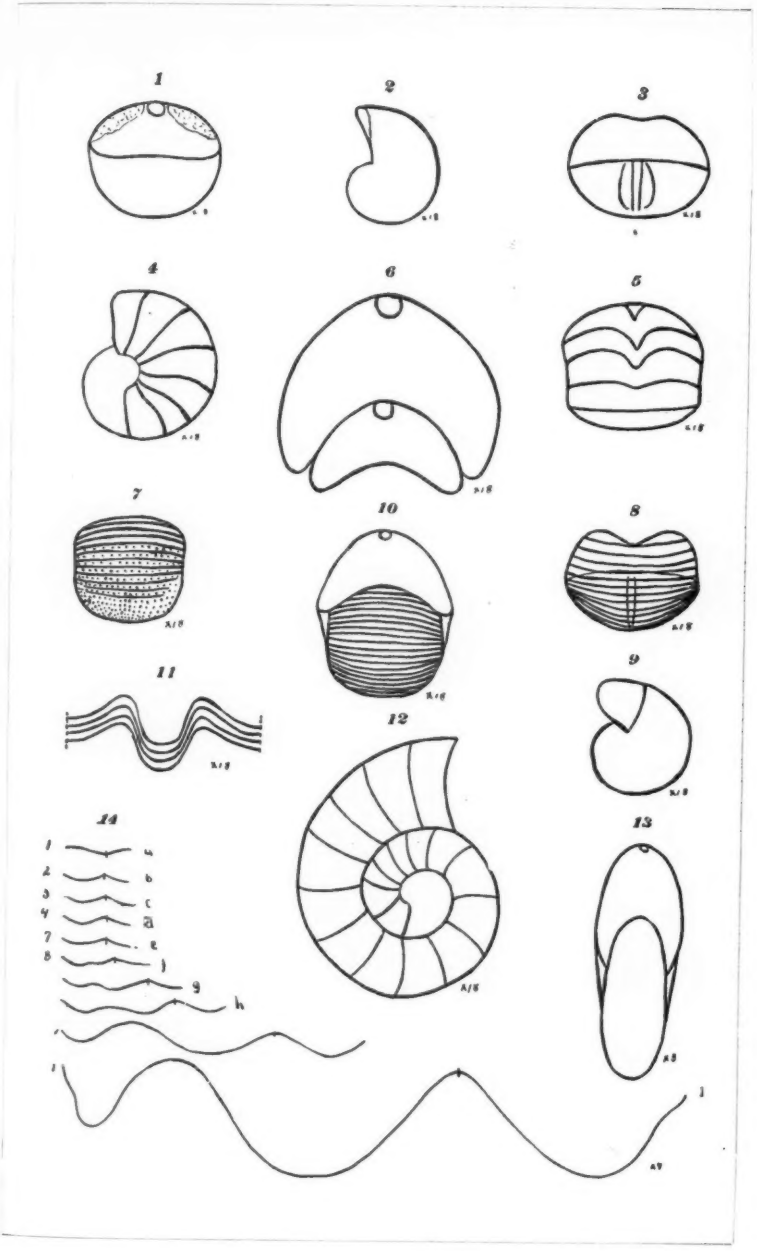
4. *L'Exposition Universelle*, Henri de Parville—Causeries scientifiques, découvertes et inventions; Progrès de la Science et de l'industrie. Vingt-neuvième année—694 pp. Paris, 1890 (J. Rothschild).—This volume gives a very full and instructive account of the French Exposition of 1889. From its first inception to its final completion nothing is overlooked, and throughout the whole book there is a clearness of presentation and profuseness of excellent illustrations which could have hardly had their origin outside of Paris.

Professor Richard Owen.—A letter to the editors from Professor G. C. Broadhead of Columbia, Missouri, states that Professor Richard Owen was assistant to Professor Norwood on the Survey of Wisconsin, Iowa and Minnesota during the year 1849, and immediately after became Professor in the Western Military Institute, located at Drennon Springs, Kentucky. About 1854, the school was transferred to Nashville, Tennessee. Mr. Owen was Professor of the Natural Sciences in the School and as such taught Chemistry, Geology and some Zoology, but also German and Spanish, besides acting as officer in a military capacity and teaching fencing.

Binney's Terrestrial Air-breathing Mollusks. A third supplement to the 5th volume, with 11 plates, has been published as Bulletin No. 4, vol. xix, by the Museum of Comparative Zoölogy, Cambridge.

Geological Survey of New Jersey, Annual Report for 1889. Also vol. ii, Part 1, of the Final Report; containing lists of the Minerals and Plants of the State.

Bulletin No. 2 (vol. i), from the Laboratories of Natural History of the State University of Iowa, contains (1) on the Anatomy of the Gorgonidæ with 10 plates, by C. C. Nutting, and (2) a Catalogue, with notes of the Native Fishes of Iowa, by Seth E. Meek.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DANA'S WORKS.

IVISON, BLAKEMAN, TAYLOR & CO., New York.—**Manual of Geology,** by J. D DANA. **Third Edition,** 1880. 912 pp. 8vo. $5.00.—**Text-book of Geology** by the same. **4th ed.** 1883. 412 pp. 12mo. $2.00.—**The Geological Story Briefly Told,** by the same. 264 pp. 12mo. 1875.

J. WILEY & SONS, New York.—**Treatise on Mineralogy,** by J. D. DANA. 5th edit. xlviii and 828 pp. 8vo., 1868. $10.00. The 5th "subedition" was issued by Wiley & Son in April, 1874. (Each "subedition" (or issue from the stereotype plates), contains corrections of all errors discovered in the work up to the date of its publication). Also, Appendix I, by G. J. Brush, 1872. Appendix II, 1875. Appendix III, 1882, by E. S. Dana.—**Manual of Mineralogy & Lithology,** by J. D. DANA. 3d edition. 474 pp. 12mo., 1878.—**Text-book of Mineralogy,** by E. S. DANA. Revised edition. 512 pp. 8vo., 1883.—**Text-book of Elementary Mechanics,** by E. S. DANA. 300 pp. with numerous cuts, 12mo., 1881.—**Manual of Determinative Mineralogy,** with an Introduction on Blow-pipe Analysis, by GEORGE J. BRUSH. 8vo., 2d ed. 1877. Third Appendix to Dana's Mineralogy, by E. S. DANA. 136 pp. 8vo. 1882.

DODD & MEAD, New York.—**Corals and Coral Islands,** by J. D. DANA. 440 pp. 8vo, with 100 Illustrations, several maps and colored plates. 3d ed., 1890.—**Characteristics of Volcanoes,** with contributions of facts and principles from the Hawaiian Islands, by J. D. DANA. 399 pp. 8vo. With illustrations, maps, etc. 1890.

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